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Autonomous Trucking Technology, Existence Acceptance, and Regulatory Preferences of Road Users: A Driving Simulation Approach

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Highlights

- Introduces and tests existence acceptance of autonomous trucks using a driving simulation experiment.
- Provides insights for policy and regulation, showing how information framing and exposure can increase public trust and support safe deployment.

Abstract

Autonomous trucks (ATs) are advancing toward limited deployment on public roads, yet public acceptance and regulatory preferences remain uncertain. This study investigates how drivers respond when sharing the road with ATs, moving beyond stated attitudes to observed behavior. We adopt the construct of existence acceptance, i.e., the degree to which non-users feel comfortable with a technology in their environment, and examine four determinants: prior experience, perceived benefits, perceived threats, and affective responses. Using a controlled driving simulation, participants encounter scripted highway scenarios involving overtaking and merging with both autonomous and human-driven trucks, as well as passenger cars. Experimental conditions vary the framing of ATs, from minimal neutral information to descriptions emphasizing regulatory safeguards and societal benefits. In-drive measures include speed, headway, gaze, heart rate, and electrodermal activity, complemented by pre- and post-drive surveys of acceptance, perceived safety, and trust. We hypothesize that richer framing will reduce arousal and stabilize driving behavior, exposure to ATs will increase acceptance, and drivers' real-time responses will differ by vehicle type. Data collection is ongoing, with results to date suggesting meaningful links between informational framing, behavioral adaptation, and post-drive perceptions. Findings will inform communication strategies, regulatory design, and safe deployment of autonomous freight technologies.

Keywords: autonomous trucks; driving simulation; public acceptance; trust; regulation

1. Introduction

Autonomous trucks (ATs) are advancing toward limited deployment on public roads, with early commercial operations already underway in states such as Arkansas and Texas (Jones et al., 2024). Beyond technical performance, their successful integration depends on how other road users respond to the technology's presence. Most research on autonomous vehicle (AV) acceptance focuses on prospective users (such as passengers who might ride in an AV) rather than the broader public who co-exist with automated systems in traffic. This gap has been highlighted in recent reviews (Gkartzonikas and Gkritza, 2019; Othman, 2021). Yet it is this day-to-day coexistence that will determine whether drivers feel comfortable sharing the road, adjust their driving behaviors, and perceive ATs as safe partners in traffic.

We adopt a coexistence perspective using the construct of *existence acceptance*—the degree to which non-users feel socially and behaviorally comfortable with a technology in their environment. Building on prior conceptual work, we identify four determinants of existence acceptance: (1) prior technology experience, (2) perceived benefits, (3) perceived threats, and (4) affective (emotional) responses. These constructs are well established in information systems and human–automation interaction literature as shaping acceptance of novel technologies (Beaudry and Pinsonneault, 2010; Naneva et al., 2020; Sun and Zhang, 2008). Prior survey-based studies confirm their importance for autonomous road technologies, showing that affective responses and perceived risks often outweigh benefits in shaping acceptance and regulatory preferences (Nair and Bhat, 2021).

While these findings provide valuable insights, they are primarily derived from stated perceptions and intentions. Much less is known about how drivers actually behave when encountering ATs in traffic, and how informational framing shapes real-time adaptation. Evidence from truck platooning suggests that real-world exposure can shift acceptance and safety perceptions in ways not predicted by surveys (Castritius, Hecht, et al., 2020; Castritius, Lu, et al., 2020), and simulator studies show that automation influences workload and vigilance among drivers (Hjälmdahl et al., 2017). Together, these studies indicate a critical gap: immediate behavioral and physiological responses may diverge from stated attitudes, with implications for both safety and long-term acceptance.

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To address this gap, we advance three hypotheses. First, richer introductory framing, emphasizing regulatory safeguards and societal benefits, will reduce physiological arousal and stabilize driving behavior (i.e., less speed variance, smoother deceleration, more consistent headways) relative to minimal information. Second, exposure to autonomous trucks in the simulation will increase post-drive existence acceptance, perceived safety, and trust compared to pre-drive baselines, across framing conditions. Third, drivers' real-time responses will differ by vehicle type: interaction with an autonomous truck will generate distinctive behavioral and physiological signatures (e.g., tighter braking profiles, higher arousal peaks, altered gaze patterns) compared to interactions with a human-driven truck or passenger car.

We test these hypotheses through a controlled driving simulation experiment. Participants experience scripted highway encounters involving both passenger cars and trucks, where trucks vary by control type (autonomous versus human-driven), predictability of maneuvers, and interaction distance during overtaking and merging. Experimental conditions also manipulate the framing of ATs, ranging from minimal neutral information to descriptions emphasizing regulatory safeguards and societal benefits. Throughout the drive, behavioral measures (e.g., speed, headway, braking, gaze) and physiological signals (heart rate, electrodermal activity) are recorded, complemented by pre- and post-drive surveys of existence acceptance, perceived safety, and trust.

This integrated design provides a dynamic test of how existence acceptance evolves through direct exposure. By linking attitudinal, behavioral, and physiological measures, the study advances beyond prior survey research to provide empirically grounded evidence of how drivers adapt to autonomous trucks in real-time. The results will inform communication strategies, human-centered regulation, and safe deployment of autonomous freight technology. Importantly, this manuscript presents work in progress: data collection is ongoing, and the analyses reported here reflect approximately half of the planned sample.

The remainder of this paper is organized as follows: Section 2 reviews prior work on AT acceptance, Section 3 details the experimental design and measures, Section 4 describes the analysis plan, Section 5 presents preliminary results, and Section 6 summarizes implications and the research next steps.

2. Literature Review

This literature review examines four interconnected strands of research relevant to autonomous trucking. First, we review studies on the technology acceptance of autonomous vehicles more broadly, with an emphasis on how non-users develop comfort or discomfort when sharing the road. Second, we acknowledge the substantial body of work on autonomous truck platooning, which has yielded early insights into driver and industry perspectives but remains distinct from our focus on single ATs. Third, we turn to the smaller but growing body of research on autonomous trucks themselves, highlighting findings on safety, trust, and regulatory preferences. Finally, we discuss simulation-based approaches that move beyond stated attitudes toward behavioral and physiological evidence. Together, these strands provide the conceptual and empirical foundation for our experimental design.

Traditional technology acceptance models emphasize users' intentions to adopt a technology. Yet in the case of autonomous vehicles, many affected individuals are not direct users but rather incidental co-present actors who must accept the technology's presence. We therefore adopt the notion of existence acceptance—the degree to which non-users feel comfortable with a technology operating in their environment (Encarnacion and Perez-Guzman, 2024). Building on information systems and human–automation interaction literatures, and on our earlier survey-based work, we identify four determinants of existence acceptance: (1) *Prior Experience*, (2) *Perceived Benefits*, (3) *Perceived Threats*, and (4) *Affective Responses*. Prior exposure to automation can normalize expectations and increase comfort, while low experience may heighten caution. Beliefs about benefits (e.g., efficiency or crash reduction) can enhance acceptance, whereas perceived risks (e.g., malfunction, cybersecurity, or loss of control) undermine it (Aliebrahimi and Miller, 2023). Affective responses, such as anxiety, vigilance, or curiosity, act as proximal drivers of comfort and regulatory preferences (Nair and Bhat, 2021).

In a driving simulator, these determinants can be linked to observable interaction patterns and psychophysiology. Headway, speed variance, braking, and gaze allocation index behavioral adaptation; heart rate and electrodermal activity capture arousal and vigilance. This integration enables a dynamic test of how framing and direct exposure influence existence acceptance in situ, extending beyond stated preferences (Ayoub et al., 2022; Chand et al., 2025; Du et al., 2020). Prior AV studies further show that explanations and framing information can shift trust (Ha et al., 2020), underscoring the importance of testing both informational and experiential effects.

The four determinants of existence acceptance also align with appraisal-based theories of emotion in human–automation contexts. Appraisal models posit that people evaluate novel technologies along dimensions such as goal relevance, controllability, and predictability; these primary and secondary appraisals shape whether a situation is construed as threatening or manageable (Kemper and Lazarus, 1992; Scherer, 2009). In encounters with an autonomous truck, unfavorable appraisals (low perceived controllability or predictability) amplify *perceived threats* and negative *affective responses*, whereas favorable appraisals (clear predictability and perceived control) bolster *perceived benefits* and curiosity. Importantly, these evaluative processes can produce autonomic arousal even when self-reports remain neutral, helping explain divergences sometimes observed between stated attitudes and in-situ adaptation.

Work on AV acceptance has largely examined consumer intentions for passenger AVs, typically extending TAM/UTAUT with perceived safety, trust, risk, and social influence (Acharya and Mekker, 2022; Panagiotopoulos and Dimitrakopoulos, 2018; Xu et al., 2018; Zhang et al., 2019, 2020). Recent studies highlight biases in public acceptance (Janatabadi and Ermagun, 2022), the role of technological readiness (Hong and Park, 2024), and acceptance patterns in specific communities (Hőgye-Nagy et al., 2023). Reviews consistently stress a consumer and willingness-to-pay orientation, with comparatively little attention to non-users who must share the road (Gkartzonikas and Gkritza, 2019; Othman, 2021). A key exception is Nair and Bhat (2021), who demonstrate that affect and prior technology experience significantly influence the perceived safety of sharing the road and support for regulation. Studies of shared AVs further demonstrate that behavioral expectations influence willingness to adopt (Greifenstein, 2024). Collectively, these findings underscore the importance of emotions, readiness, and experience, but the evidence base is predominantly survey-based and attitudinal.

Research on autonomous truck platooning (ATP) is more mature, but focuses on professional drivers and firms. Driver studies show that acceptance hinges on trust, workload, and experience, with mixed effects on fatigue and situation awareness in simulators (Castritius, Hecht, et al., 2020; Hjälmdahl et al., 2017). Field and survey studies also suggest that real-road exposure can increase perceived ease and safety, although monotony and loss of autonomy at work remain concerns (Bhoopalam et al., 2023; Castritius, Lu, et al., 2020). From the firm side, risk and adoption studies emphasize business models, peer effects, and regulatory conditions (Münch et al., 2021; Simpson et al., 2022; Talebian and Mishra, 2022). Broader analyses underline safety, infrastructure readiness, and policy as key deployment constraints (Paddeu and Denby, 2022; Schirrer et al., 2022; Simoes et al., 2022). While this strand demonstrates the promise and limits of ATP, its focus on truck drivers and freight operators highlights the absence of evidence on how general road users adapt to single ATs in mixed traffic—the focus of our study.

Compared to platooning, studies of single ATs are fewer and often framed from the perspective of drivers, companies, or industry experts. Professional drivers express mixed acceptance shaped by trust and job-security concerns (Fröhlich et al., 2018; Marisda et al., 2024; Orii et al., 2021; Talebian and Mishra, 2022), and surveys of public stakeholders highlight safety and liability as salient issues (Dougherty et al., 2017; Kapser and Abdelrahman, 2020). Industry-oriented reviews stress that regulatory harmonization and public acceptance are preconditions for scaling (Engström et al., 2019). Early interview and focus group work suggests that road users favor visible safety cues, human oversight, or geo-fenced operations to feel secure with ATs (Neubauer et al., 2020). These studies converge on the importance of trust, safety, and regulation, but remain largely descriptive and rely on self-reporting.

Despite policy and industry interest, there is a notable scarcity of behavioral evidence on how non-truck-driver road users adapt when interacting with ATs. Simulator studies have primarily examined truck drivers in platooning contexts, reporting effects on workload, drowsiness, and acceptance (Hjälmdahl et al., 2017), rather than passenger-car drivers facing ATs in mixed traffic. There is limited experimental work that (i) exposes ordinary drivers to scripted encounters with ATs (e.g., merges and overtakes) and (ii) manipulates information framing (minimal vs. benefits/regulatory context).

Introductory or framing information plays a crucial role in shaping how people form expectations about automated systems. Such information functions as a *prime*—it shapes individuals' mental models of the system's reliability, predictability, and control before any direct interaction occurs. Richer introductions that explain how automation operates or highlight safety mechanisms can calibrate trust, making behaviors appear more predictable and reducing anxiety during encounters. In contrast, minimal or ambiguous framing tends to heighten uncertainty, leading to cautious or defensive driving responses (Körber et al., 2018; Pataranutaporn et al., 2023).

In automated driving, these effects extend beyond attitudes to observable behavior and physiology: primed participants allocate attention differently, adjust following distances, and exhibit distinct arousal profiles when interacting with automated vehicles. The modality of introductory information also matters—text or visuals can convey core facts, but experiential formats such as videos or short familiarization drives better align mental models and increase comfort. Building on this evidence, our experiment varies the richness of introductory framing to test how pre-drive expectations translate into differences in acceptance, perceived safety, and behavioral adaptation.

Evidence from adjacent AV acceptance studies suggests that affect and experience should modulate in-drive behavior and post-drive attitudes (Nair and Bhat, 2021), and ATP survey findings point to potential conflict behaviors (e.g., platoon cut-ins) that could generalize to AT encounters (Castritius, Lu, et al., 2020). Yet these hypotheses have not been tested using integrated behavioral, physiological, and gaze measures in controlled driving simulator experiments with ATs.

Across the literature, the dominant methods are surveys and interviews; behavioral and psychophysiological responses to ATs among general road users remain underexplored. This study addresses that gap by linking our existence-acceptance framework to observed interaction patterns and arousal in a controlled simulator. We test whether richer introductory information reduces arousal and stabilizes driving behavior, whether direct exposure increases post-drive existence acceptance, perceived safety, and trust, and whether interactions with ATs elicit distinct real-time behavioral/physiological signatures compared to manual trucks and passenger cars. In doing so, we move the literature from stated attitudes toward empirically grounded interaction evidence that can inform communication strategies and regulation (e.g., human oversight, dedicated lanes, geo-fencing) highlighted in prior work (Castritius, Lu, et al., 2020; Dougherty et al., 2017; Engström et al., 2019).

3. Study Objectives and Design

The study is organized in three parts. The overarching goal is to examine how balanced informational framing and direct exposure to an AT influence road users' existence acceptance, perceived safety, trust, and real-time interaction behavior. A controlled highway simulation delivers consistent, repeatable encounters, guiding each participant from check-in through debrief under a standardized protocol.

3.1 Objectives

Three objectives structure the experimental design:

1. **Test the effect of introductory information on driver responses.** We vary the information given to participants *before* they encounter an AT—ranging from basic facts only, to additional regulatory context, to regulatory context plus benefits. We test whether framing moderates in-drive behavioral, physiological, and gaze responses during AT encounters (e.g., calmer driving due to reduced uncertainty, as suggested by HRI trust studies).

2. **Assess changes in acceptance after simulated exposure.** We measure attitudes (existence acceptance of ATs, perceived safety, trust) before and after the drive to determine whether sharing the road with an AT in the simulator changes these attitudes relative to baseline, and whether changes are larger under richer information.

3. **Compare responses across vehicle types in matched encounters.** Each participant experiences an autonomous truck (AT), a human-driven truck (MT), and a passenger car (C) in matched overtake–merge episodes. We compare real-time responses (speed

adjustments, following distance, mirror checks/gaze, physiological arousal) across vehicle types to identify any patterns unique to AT interactions.

These aims correspond to the between-subjects framing manipulation (Objective 1), the pre–post attitudinal change (Objective 2), and the within-subject vehicle-type contrasts (Objective 3). Together, they allow us to examine acceptance from multiple angles: psychologically (via attitude change and framing effects) and behaviorally (via actual driving interactions).

3.2 Hypotheses

Grounded in prior work on technology experience, perceived benefits/threats, and affective response (Section 2), we test:

1. **H1 (Framing effect).** A more comprehensive introduction (regulatory context and benefits) yields lower arousal (smaller increases in heart rate/skin conductance) and more stable driving (less speed variance, smoother deceleration, steadier lateral position) during AT encounters than minimal information Körber et al., 2018.

2. **H2 (Exposure effect on attitudes).** Direct exposure to an AT increases post-drive existence acceptance, perceived safety, and trust versus pre-drive baselines, with larger positive shifts under richer information.

3. **H3 (Vehicle-type differences).** Drivers' real-time responses differ by encountered vehicle. Relative to MT and C, AT encounters elicit distinctive behavioral/physiological signatures (e.g., slightly larger speed reductions, longer headways, more mirror checks, higher arousal peaks), especially in early exposures.

In addition to these primary hypotheses, we are also interested in exploratory questions, such as whether individual differences (age, prior tech experience, etc.) moderate these effects, and how regulatory preferences relate to acceptance. While not formalized as hypotheses here, we expect, for instance, that participants with lower post-drive acceptance might favor stricter regulations on ATs (like requiring human oversight or limiting operating areas), whereas those with high acceptance might be open to more integration.

3.3 Experimental Design Overview

To test these expectations under controlled conditions, we implemented a mixed experimental design. The design has a between-subjects factor for the *information framing condition* and within-subjects factors for *vehicle exposures* during the drive. All participants complete the same highway scenario; only framing and the order of vehicle-type exposures vary.

Information conditions (between subjects). Participants are randomly assigned to one of three information conditions prior to driving, as described below:

1. **Basic Information (BI):** Participants receive a concise overview explaining what an autonomous truck (AT) is—essentially, a truck equipped with sensors, cameras, and decision software that allow it to operate with varying levels of automation. This overview also covers what such a truck might do on the road (e.g., lane keeping, lane changing, following traffic rules) in neutral, factual terms. No details about regulations or benefits are given in this condition. It represents a minimal knowledge scenario.

2. **BI + Regulatory Information (BI+RI):** In addition to the basic description, participants learn about common early deployment practices and regulations for ATs. This includes brief, neutral statements, such as: ATs initially operate in limited domains or lower-risk conditions (for example, only on highways during daylight hours, or only in certain states with clear legislation). The information is factual and does not promise benefits; its purpose is to set an expectation of oversight and caution in current deployments.

3. **BI + RI + Perceived Benefits (BI+RI+PB):** Participants receive everything in BI+RI, *plus* a short summary of potential societal benefits of ATs. For example, they are informed that experts anticipate improvements in logistics efficiency, reductions in driver fatigue-related accidents, and economic benefits, as well as potential environmental and congestion benefits from optimized driving. These points are presented in a balanced way (not as hype, but as plausible advantages). This condition is the most informative and positive framing, designed to see if highlighting benefits further eases participants' minds or biases them to be more accepting.

All informational content is delivered via a short narrated video/slideshow of similar length, with the only differences being the inclusion of the extra context and benefits.

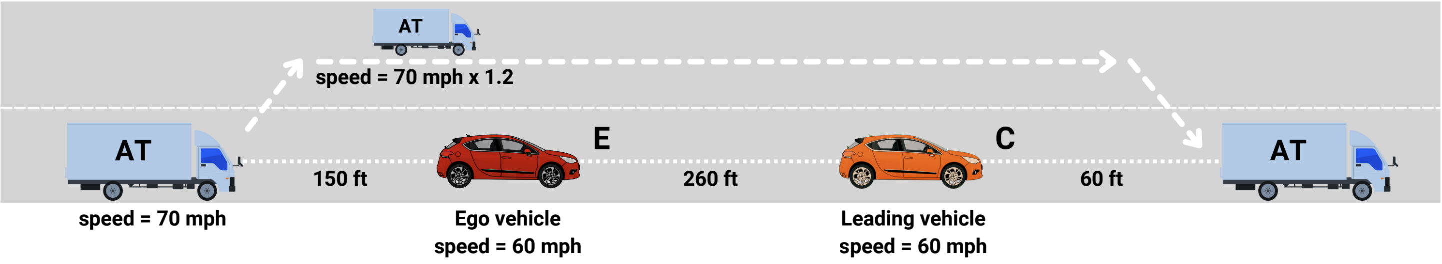

Figure 1: Exposure levels and encounter timing within the highway scenario.

Driving scenario and vehicle exposures (within subjects). Figure 1 illustrates the structure of the highway simulation and the sequence of exposure episodes. Participants drove an *ego vehicle* in the right lane, following a *lead vehicle* positioned approximately **260 ft** ahead at the start of each scenario. During repeated exposure episodes, a *following vehicle* approached from behind, overtook in the left lane, and merged back ahead of the traffic stream. Across episodes, the following vehicle alternated among three types: an *autonomous truck (AT)*, a *human-driven truck (MT)*, and a *passenger car (C)*. Short forms (AT, MT, C) are used consistently throughout the manuscript.

Each overtaking episode followed standardized timing and geometry for comparability: the following vehicle closed to roughly **150 ft** behind the ego vehicle, changed to the left lane, accelerated to about **120%** of the participant's current speed (nominally near **70 mph**), passed the ego and lead vehicles, and merged back into the right lane ahead of the lead vehicle (typically completing the merge about **60 ft** in front of the lead). Buffer segments were inserted between episodes to prevent overlap of response windows. Encounter features—such as merge distance and maneuver smoothness—varied orthogonally across episodes to maintain realism while preserving control. The order of vehicle types and encounter variations was **counterbalanced** across participants.

3.4 Study Flow

Figure 2 summarizes the procedure from consent to debrief. The study protocol was approved by the Institutional Review Board, and all participants provided informed consent prior to participation.

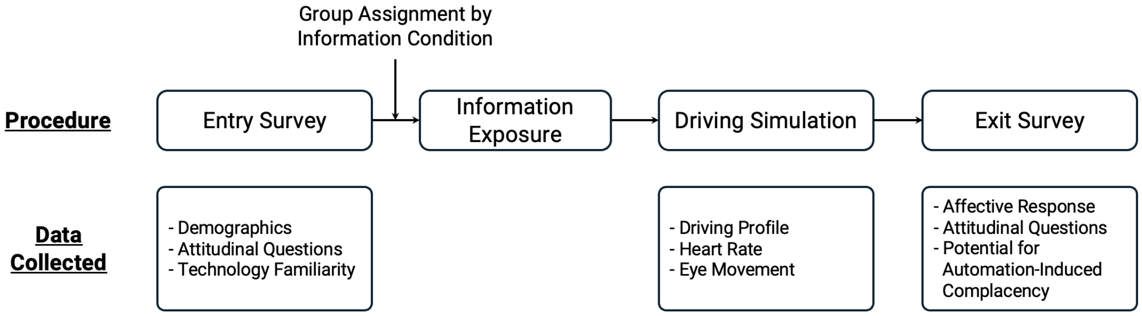

Figure 2: Schematic overview of the experimental procedure and data collection.

Check-in and consent. Participants first reviewed study details, risks, and compensation, then provided written consent.

Entry survey (baseline). Before the simulator session, participants completed a baseline questionnaire capturing demographics and pre-drive attitudes (existence acceptance, perceived safety, trust) as well as determinant constructs (e.g., prior technology experience, perceived benefits, perceived threats, affective responses). Detailed item wording, scales, and reliability statistics are reported in Section 4.

Information exposure. Participants were shown the introductory information corresponding to their assigned condition (BI, BI+RI, or BI+RI+PB). This was presented through a short five-minute narrated video with visuals. The video also introduced a color scheme that distinguished autonomous from human-driven trucks, ensuring participants could easily recognize each vehicle type during the drive. Questions were addressed afterward to clarify the concept of an autonomous truck while avoiding disclosure of study hypotheses.

Familiarization, calibration, and pre-drive briefing. After viewing the introductory video, participants were guided from the survey station to the simulator area. The experimenter introduced the simulator's basic controls, confirmed participants' understanding, and supervised a short three-minute familiarization drive. This session aimed to mitigate novelty effects, establish baseline physiological stability, and verify that all recording systems were functioning properly. Participants then rested briefly while receiving final driving instructions: they were to maintain their lane, keep a maximum speed of 60 mph, and follow the lead vehicle at a safe distance. They were reminded that the blue truck represented an autonomous truck (AT), the white truck a human-driven truck (MT), and the sedan a regular passenger car, and that they could pause or withdraw from the study at any point.

Main simulation. Participants then completed the highway scenario with repeated overtake–merge episodes (AT, MT, C) as described earlier. Instructions were minimal—participants were told only to "drive normally and follow the road." They typically remained behind the lead vehicle while other vehicles executed passing maneuvers. The drive lasted approximately ten minutes, during which vehicle telemetry, gaze, and physiological data were recorded continuously and time-synchronized with event markers.

Exit survey and debrief. Immediately after completing the simulation, participants repeated the key attitudinal measures (existence acceptance, perceived safety, trust) and completed additional post-drive self-assessment surveys to capture emotional and cognitive responses. A brief semi-structured interview followed, allowing participants to elaborate on their experiences and provide qualitative insights that might not be captured through the survey.

This standardized procedure ensured that all participants experienced comparable conditions, with only the intended experimental variables—information condition and counterbalanced encounter order—varying across participants. The design enables clear comparisons across framing conditions, pre- and post–attitudinal change, and within-person responses to different vehicle types, while preserving ecological validity in a realistic highway context.

4. Data and Methods

4.1 Participants

At the time of writing, 32 participants have completed the study out of a target sample of 51 (17 per framing condition). All participants provided informed consent and received compensation for a one-hour session. Participants were recruited from the university community, yielding variation in age, gender, and driving experience. Demographic characteristics of the collected sample are reported in Section 5.1.

4.2 Apparatus

The experiment was conducted using the NADS MiniSim v2.2.1 fixed-base driving simulator, equipped with three wrap-around displays providing approximately a 160° horizontal field of view, a steering wheel, pedals, and a driver's seat with tactile feedback. The simulator was programmed to emulate highway driving, allowing precise control of traffic scenarios, vehicle behavior, and environmental conditions.

Following the introductory video, participants were fitted with multimodal sensors. An Empatica Embrace 2 wristband, worn on the non-dominant hand, continuously recorded electrodermal activity (EDA) and heart rate (HR), calibrated during a short familiarization drive to ensure stable physiological baselines. Gaze data were collected using Pupil Labs NEON eye-tracking glasses (60 Hz), calibrated during a brief rest period to align gaze mapping with the visual scene. Physiological and gaze data streams were time-synchronized with simulator event markers, enabling precise alignment of behavioral, physiological, and perceptual responses during overtaking and merging events. Vehicle telemetry—including speed, acceleration, braking, and time headway—was logged automatically, providing behavioral indicators of driver response to each vehicle type. Together, these multimodal data streams supported integrated analyses of behavioral, physiological, and perceptual adaptation to autonomous truck encounters under different framing conditions.

4.2.1 Survey Measures

Survey instruments served as an additional component of the experimental apparatus, capturing attitudinal, affective, and experiential responses before and after simulator exposure. All surveys were administered electronically and synchronized with the experimental sequence. Measured constructs included *Technology Experience* (TE), *Perceived Benefits* (PB), *Perceived Threats* (PT), *Affective Responses* (AR), *Support for Regulations* (SR), and three affective dimensions from the *Self-Assessment Manikin* (SAM): *Arousal*, *Valence*, and *Dominance*. Items were adapted from validated scales in automation and emotional appraisal research. Table 1 summarizes representative items and scale anchors.

Notation	Measurement	Scale
TE	**Technology Experience**	
How often do you use the following features?		
TE1	Adaptive cruise control.	Never – Always
TE2	Automatic lane correction.	Never – Always
TE3	Automated parking.	Never – Always
PB	**Perceived Benefits**	
PB1	Driverless trucks will make transporting goods cheaper.	Strongly Disagree – Strongly Agree
PB2	Driverless trucks will make products cheaper.	Strongly Disagree – Strongly Agree
PB3	Driverless trucks will improve delivery efficiency.	Strongly Disagree – Strongly Agree
PB4	Driverless trucks will help reduce congestion.	Strongly Disagree – Strongly Agree
PB5	Driverless trucks will replace jobs (reverse-coded).	Strongly Disagree – Strongly Agree
PT	**Perceived Threats**	
PT1	I am afraid of sharing the road with driverless trucks.	Strongly Disagree – Strongly Agree
PT2	Driverless trucks can easily lose control.	Strongly Disagree – Strongly Agree
PT3	Driverless trucks may crash with other vehicles.	Strongly Disagree – Strongly Agree
PT4	Driverless trucks may crash with pedestrians.	Strongly Disagree – Strongly Agree
AR	**Affective Response**	
If you encounter an autonomous truck while driving, how much would you feel?		
AR1	Anxious.	Not at all – To a great extent
AR2	Excited.	Not at all – To a great extent
AR3	Interested.	Not at all – To a great extent
AR4	Scared.	Not at all – To a great extent
SR	**Support for Regulations**	
SR1	Driverless trucks must only travel on highways.	Strongly Disagree – Strongly Agree
SR2	Driverless trucks must travel on dedicated lanes.	Strongly Disagree – Strongly Agree
SR3	Driverless trucks should avoid areas like schools.	Strongly Disagree – Strongly Agree
SR4	Driverless trucks should only operate at night.	Strongly Disagree – Strongly Agree
SR5	A person should always be in driverless trucks to take over if necessary.	Strongly Disagree – Strongly Agree
SAM	**Self-Assessment Manikin (Affective Dimensions)**	
SAM1	Arousal — from calm or relaxed to highly excited or tense.	1 (Calm) – 9 (Excited)
SAM2	Valence — from unpleasant or unhappy to pleasant or happy.	1 (Unpleasant) – 9 (Pleasant)
SAM3	Dominance — from submissive or controlled to dominant or in control.	1 (Passive) – 9 (Dominant)

Table 1: Survey constructs and representative items used to measure attitudinal and affective responses.

Scoring and interpretation. For multi-item constructs (TE, PB, PT, AR, SR), individual item responses were averaged to form composite indices, with PB5 reverse-coded prior to aggregation. All items in these constructs used a 1–5 Likert-type scale, where higher values indicate stronger endorsement of the underlying construct (e.g., greater perceived benefit or threat, higher affective intensity, or stronger regulatory support). The three SAM dimensions—Arousal, Valence, and Dominance—were each rated on a 1–9 scale and analyzed as continuous indicators of post-drive affective state. These survey-based measures serve as both dependent and explanatory variables in subsequent analyses (Section 5).

4.3 Independent and Dependent Variables

The study incorporated both between- and within-subject factors consistent with its mixed experimental design.

Independent variables included several sources of variation. The information condition (BI, BI+RI, BI+RI+PB) was manipulated between subjects to test whether richer introductory framing influences participants' responses. Within-subject variation was introduced through the *vehicle type* (AT, MT, C) across repeated overtaking and merging encounters, allowing each participant to serve as their own control. Additional encounter parameters—such as merge distance (near vs. far) and maneuver smoothness (smooth vs. erratic)—were systematically varied to reproduce realistic traffic dynamics under controlled conditions. Participant-level characteristics (e.g., age, gender, driving experience, and baseline attitudes) were recorded as covariates and examined in exploratory analyses to capture individual differences in adaptation.

Dependent variables spanned four domains of response. Attitudinal responses included existence acceptance, perceived safety, trust in autonomous trucks, and support for regulation, assessed both pre- and post-drive to capture attitudinal change. Behavioral responses were derived from simulator telemetry, including speed profiles, braking intensity, time headway, and lateral lane position, which indicated how participants modulated control during each vehicle encounter. Physiological responses were measured by changes in heart rate (HR) and phasic electrodermal activity (EDA), normalized to baseline, to index baseline, indexing arousal and vigilance during potentially stressful episodes. Finally, gaze responses, extracted from eye-tracking data, included mirror checks, glance frequency, and fixation duration, providing a window into participants' visual attention allocation toward different vehicle types and conditions.

Together, these multimodal measures triangulate attitudinal changes with observed behavioral and physiological adaptation, providing a comprehensive picture of how information framing and direct exposure shape road users' responses to autonomous trucks.

4.4 Modeling Approach

This section outlines the analytical framework designed to address the three study objectives. Preliminary descriptive and inferential analyses have been conducted with the current dataset, while the modeling strategy below describes the full set of analyses to be implemented once the target sample is complete. The framework integrates attitudinal, behavioral, physiological, and psychological data using multilevel and regression-based approaches suited to the multimodal and repeated-measures structure of the experiment.

For **Objective 1**—examining framing effects on in-drive behavior and physiology—linear mixed-effects models (LMMs) will be used to test whether the level of introductory information moderates behavioral and physiological responses during simulated encounters. Information condition and vehicle type will be modeled as fixed effects, with participant-level intercepts as random effects. Dependent variables will include driving dynamics (e.g., speed, braking intensity, and time headway) and physiological indicators (e.g., heart-rate change and EDA peaks) derived from event-centered time windows around overtaking and merging episodes. All features will be normalized relative to participant baselines to ensure comparability. Supporting analyses, such as two-way ANOVA on aggregated measures, will be conducted as robustness checks, with post-hoc contrasts probing significant effects.

For **Objective 2**—assessing exposure effects on attitudes—preliminary analyses were conducted using multilevel modeling (`lme4`, `lmerTest` in R) to account for repeated pre–post measurements within participants. Fixed effects included *Time* (pre vs. post), *Information Condition* (BI, BI+RI, BI+RI+PB), and their interaction, with participant ID as a random intercept. This specification captures both average changes in attitudes and individual-level variability in baseline acceptance. Model diagnostics confirmed normality of residuals, and post-hoc pairwise comparisons were performed using estimated marginal means (`emmeans`) with Benjamini–Hochberg correction ($\alpha = .05$). When the full sample is obtained, this model structure will be used to test whether richer introductory framing amplifies positive changes in existence acceptance, perceived safety, and trust. A difference-in-differences (DiD) framework will also be applied as a robustness check, treating post-exposure and information condition as interacting predictors. Change scores computed from matched survey items will supplement model-based estimates.

For **Objective 3**—comparing vehicle-type contrasts across multimodal responses—post-drive affective and anxiety measures, Self-Assessment Manikin (SAM) and State-Trait Anxiety Inventory (STAI), were analyzed using linear regression models to test for condition effects. Twelve outcomes were examined (three SAM dimensions × three vehicle types + three STAI scores), followed by post-hoc comparisons using estimated marginal means with Benjamini–Hochberg correction ($\alpha = .05$). Descriptive statistics (means, SDs) and effect sizes were reported. Upon completion of data collection, LMMs will extend these analyses to behavioral, physiological, gaze, and psychological responses across vehicle types (AT, MT, and C). Fixed effects will include vehicle type, with participant intercepts as random effects. Exploratory analyses, such as repeated-measures ANOVA or clustering, may be employed to identify multimodal response patterns, with encounter episodes serving as the unit of analysis. Where feasible, multimodal fusion techniques will be explored to jointly model behavioral and affective responses.

This modeling framework provides a coherent structure linking information framing, exposure, and multimodal driver responses. Preliminary results presented in Chapter 5 validate the modeling design and offer early insights into framing-related differences in attitudes and emotional adaptation, which will be further tested through the full inferential analyses once the target sample is complete.

5. Preliminary Results

Regarding preliminary results, data from 32 participants have been matched across pre- and post-drive surveys. Analyses are exploratory, focusing on descriptive statistics and simple contrasts, with full modeling reserved for the complete sample. These early findings offer an initial insight into how information framing and simulated exposure to ATs influence perceptions of acceptance, trust, and safety.

5.1 Participant Demographics

Table 2 presents the demographic characteristics of the current sample (N = 32), including gender, Hispanic origin, race/ethnicity, education, and employment status, alongside corresponding reference values for the U.S. population (U.S. Census Bureau, 2024). This table provides a direct comparison between the participant sample and national-level benchmarks to contextualize representativeness.

Table 2: Demographic characteristics of participants (N = 32) compared with U.S. Census benchmarks.

Attribute	N	(%)	US%	Attribute	N	(%)	US%
Gender				**Employment Status**			
Male	20	62.5	48.6	Employed (Full/Part-Time)	11	34.4	63.5
Female	12	37.5	51.4	Student	21	65.6	N/A
				Unemployed/Retired	0	0.0	36.5
Education Level				**Race and Ethnicity**			
High School or Less	16	50.0	54.6	Asian	18	56.2	6.7
Some College	9	28.1	40.9	Black or African American	2	6.2	13.9
Graduate Degree	7	21.9	4.5	Hispanic or Latino	3	9.4	19.1
				White	11	34.4	69.6
				Other	1	3.1	9.7

As shown in Table 2, the sample included 20 male (62.5%) and 12 female (37.5%) participants. Most participants were students (65.6%), with the remainder reporting full- or part-time employment (34.4%). Half of the participants (50.0%) reported a high school education or less, 28.1% had some college experience, and 21.9% held a graduate degree. In terms of race and ethnicity, 56.2% of participants identified as Asian, 34.4% as White, 9.4% as Hispanic or Latino, 6.2% as Black or African American, and 3.1% as Other. Overall, the sample was predominantly Asian and student-based, with higher educational attainment than the national average—reflecting its university recruitment context.

5.2 Baseline Attitudes and Support for Regulations

Table 3 summarizes participants' baseline attitudes toward autonomous trucking and their support for related regulations. Constructs were computed as the mean of their respective Likert-scale items (1–5), with PB5 reverse-coded. The table provides descriptive statistics based on the entry survey responses from 32 participants.

Table 3: Baseline Attitudinal Constructs (N = 32).

Construct	Mean	SD
Perceived Benefits (PB)	3.52	0.55
Perceived Threats (PT)	2.93	0.78
Affective Responses (AR)	3.65	0.86
Support for Regulations (SR)	3.38	0.81
Technology Experience (TE)	–	–

As shown in Table 3, participants reported moderately positive baseline attitudes toward autonomous trucking. Perceived Benefits (M = 3.52, SD = 0.55) were generally higher than Perceived Threats (M = 2.93, SD = 0.78), indicating a more optimistic than risk-oriented outlook. Affective Responses (M = 3.65, SD = 0.86) suggest a mixture of curiosity and mild apprehension toward autonomous vehicles. Support for Regulations (M = 3.38, SD = 0.81) was moderate, indicating balanced views regarding policy restrictions such as highway-only operation or human oversight.

Technology Experience (TE) was excluded from this summary due to sparse valid responses, reflecting limited prior use of automated driving features (e.g., adaptive cruise control, lane keeping, automated parking). This aligns with the participant pool's demographic composition—primarily students and early-career drivers—with fewer reporting extensive hands-on experience with vehicle automation.

Overall, the results depict a sample that is relatively open to the technology yet remains cautious about safety and regulation, providing a realistic baseline for interpreting changes after simulator exposure.

Table 4: Support for Regulation (SR) Items: Percentage Endorsements (Entry Survey, N = 32).

Regulation Item	**Strongly Disagree**	**Somewhat Disagree**	**Neutral**	**Somewhat Agree**	**Strongly Agree**
Highways-only operation	6.3	3.1	12.5	59.4	18.8
Dedicated lanes	3.1	18.8	21.9	40.6	15.6
Restricted near schools	0.0	9.4	18.8	34.4	37.5
Night-only operation	12.5	25.0	46.9	12.5	3.1
Human-in-the-loop	0.0	9.4	9.4	43.8	37.5

Table 4 details the entry-survey responses for the regulatory-support construct. Most participants endorsed the need for some operational restrictions, particularly for school zones and highway-only operation, while showing mixed opinions toward night-only restrictions. Support for human oversight remained high, with over 80% somewhat or strongly agreeing that a person should remain in control as a backup driver. These baseline attitudes provide a reference for evaluating post-exposure shifts in regulatory support.

5.3 Psychological Metrics

This subsection presents preliminary analyses addressing Objective 1, which examines the framing effect on in-drive affective and physiological responses. Figure 3 illustrates participants' emotional ratings across the three Self-Assessment Manikin (SAM) dimensions—arousal, valence, and dominance—toward the three vehicle types, stratified by condition group (A, B, C).

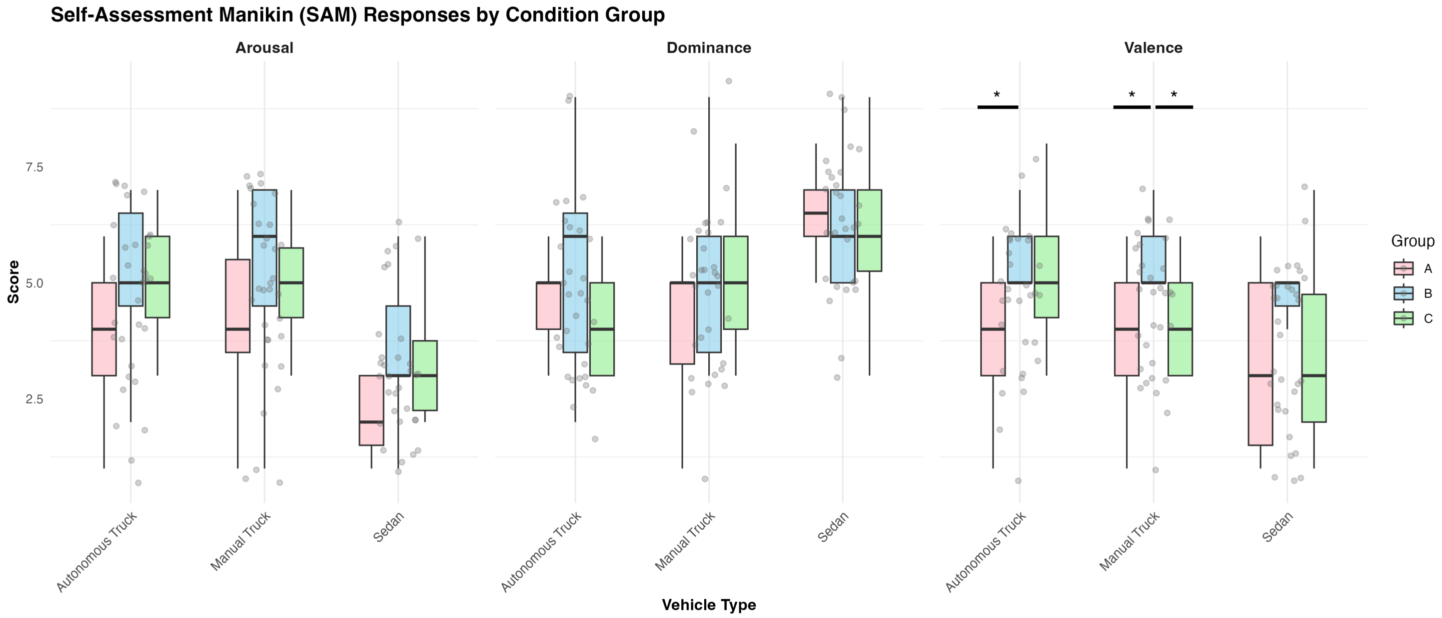

Figure 3: Self-Assessment Manikin (SAM) Ratings by Vehicle Type and Information Condition. Asterisks indicate significant group differences ($p < 0.05$).

Overall, higher arousal and valence were observed for both truck types compared to the passenger car, while dominance scores were slightly higher for the passenger car. No significant differences were found between autonomous trucks (ATs) and manual trucks (MTs) for any of the three affective dimensions. This pattern suggests that participants felt greater discomfort and reduced control when driving around trucks in general, but that truck autonomy itself did not substantially alter these affective responses.

Furthermore, after Benjamini–Hochberg correction, significant group effects emerged for valence toward ATs and MTs. *(1) Valence toward ATs:* A main effect of information condition was detected ($F(2, 29) = 4.55$, $p = 0.019$), indicating that participants differed significantly in their pleasure ratings. Post-hoc tests showed that Group A reported lower valence for ATs compared with both Group B ($\beta = -1.64$, $SE = 0.58$, $p = 0.026$) and Group C ($\beta = -1.37$, $SE = 0.59$, $p = 0.042$). Groups B and C did not differ, suggesting that moderate to high informational framing elicited similarly positive affective evaluations compared with minimal framing. *(2) Valence toward MTs:* A significant main effect was also found for MTs ($F(2, 29) = 4.26$, $p = 0.024$). Group B reported higher valence than Group A ($\beta = -1.46$, $SE = 0.54$, $p = 0.035$) and Group C ($\beta = 1.26$, $SE = 0.55$, $p = 0.045$), indicating that the affective impact of framing was specific to the moderate-information condition. Group C did not differ from Group A ($p = 0.73$).

Taken together, these results indicate that the condition group, specifically the information framing, has a minimal impact on individuals' psychological dimensions towards the technology of the trucks.

5.4 Attitudinal Outcomes

This subsection presents the initial analysis, focusing on objective 2, specifically the framing of information and exposure effects on attitudes. Table 5 depicts the post-drive attitudes for perceived benefits and threats, support for regulations, existence acceptance, and perceived safety.

Table 5: Post-Drive Attitudes and Changes from Baseline (N = 32).

Measure	**Mean**	**SD**
Perceived Benefits (PB, post)	3.62	0.58
Perceived Threats (PT, post)	2.63	0.80
Support for Regulations (SR, post)	3.25	0.84
Acceptance: Trucks	3.69	0.86
Acceptance: Any Driverless Vehicle	3.88	0.66
Perceived Safety	3.34	1.04

As shown in Table 5, participants' post-drive attitudes reflect a generally positive orientation toward autonomous trucking. Perceived Benefits (M = 3.62, SD = 0.58) remained higher than Perceived Threats (M = 2.63, SD = 0.80), suggesting that participants viewed autonomous trucks as offering more advantages than risks after direct exposure. Support for Regulations (M = 3.25, SD = 0.84) was moderate, consistent with balanced views on operational restrictions. Acceptance levels were relatively high for both autonomous trucks (M = 3.69, SD = 0.86) and driverless vehicles in general (M = 3.88, SD = 0.66), while Perceived Safety (M = 3.34, SD = 1.04) showed greater variability across individuals.

Overall, these findings suggest that after the simulator experience, participants tended to maintain or slightly reinforce their positive attitudes toward automation, perceiving benefits more strongly than threats and supporting regulatory oversight at moderate levels.

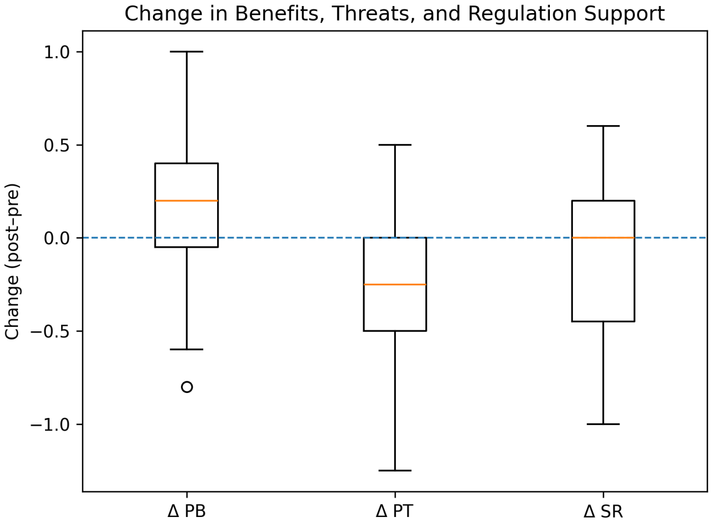

Figure 4: Individual-level changes (Δ) from pre to post in Perceived Benefits (PB), Perceived Threats (PT), and Support for Regulation (SR). Boxes show notched medians and mean lines; points show participant-level changes; dashed line marks no change.

As shown in Figure 4, changes from pre- to post-survey responses reveal a slight increase in perceived benefits ($\Delta\text{PB} > 0$) and a moderate reduction in perceived threats ($\Delta\text{PT} < 0$), while support for regulation ($\Delta\text{SR} \approx 0$) remained largely stable. This pattern suggests that direct exposure to autonomous trucking in the simulator may help strengthen participants' recognition of potential benefits and reduce perceived risks, without notably shifting their views on regulatory oversight at this stage of data collection.

To further explore the role of exposure to AT driving in interaction with information framing, Figure 5 displays participants' composite scores before and after exposure to different levels of information across three groups (A, B, and C). The boxplots illustrate changes in perceived benefits, support for regulation, and perceived threats, highlighting pre–post differences within each information condition.

Support for Regulatory Restrictions. we observed a significant main effect of pre-post attitude change ($\beta = -2.27$, $SE = 0.67$, $p = 0.002$), indicating an overall decrease in support from pre- to post-measurement. Post-hoc comparisons showed that Group A showed a significant reduction from pre ($M = 16.3$) to post ($M = 14.0$), whereas Groups B and C exhibited smaller, non-significant decreases ($p > 0.15$). We did not observe an interaction effect between pre-post attitude change and different group responses ($p > 0.17$), suggesting a consistent time effect across groups

Perceived Benefits. For perceived benefits, we found a significant pre-post attitude response and different groups, ($\beta = 2.05$, $SE = 0.79$, $p = .015$), indicating condition-specific differences in change patterns. Through Post-hoc analyses, we found that Group

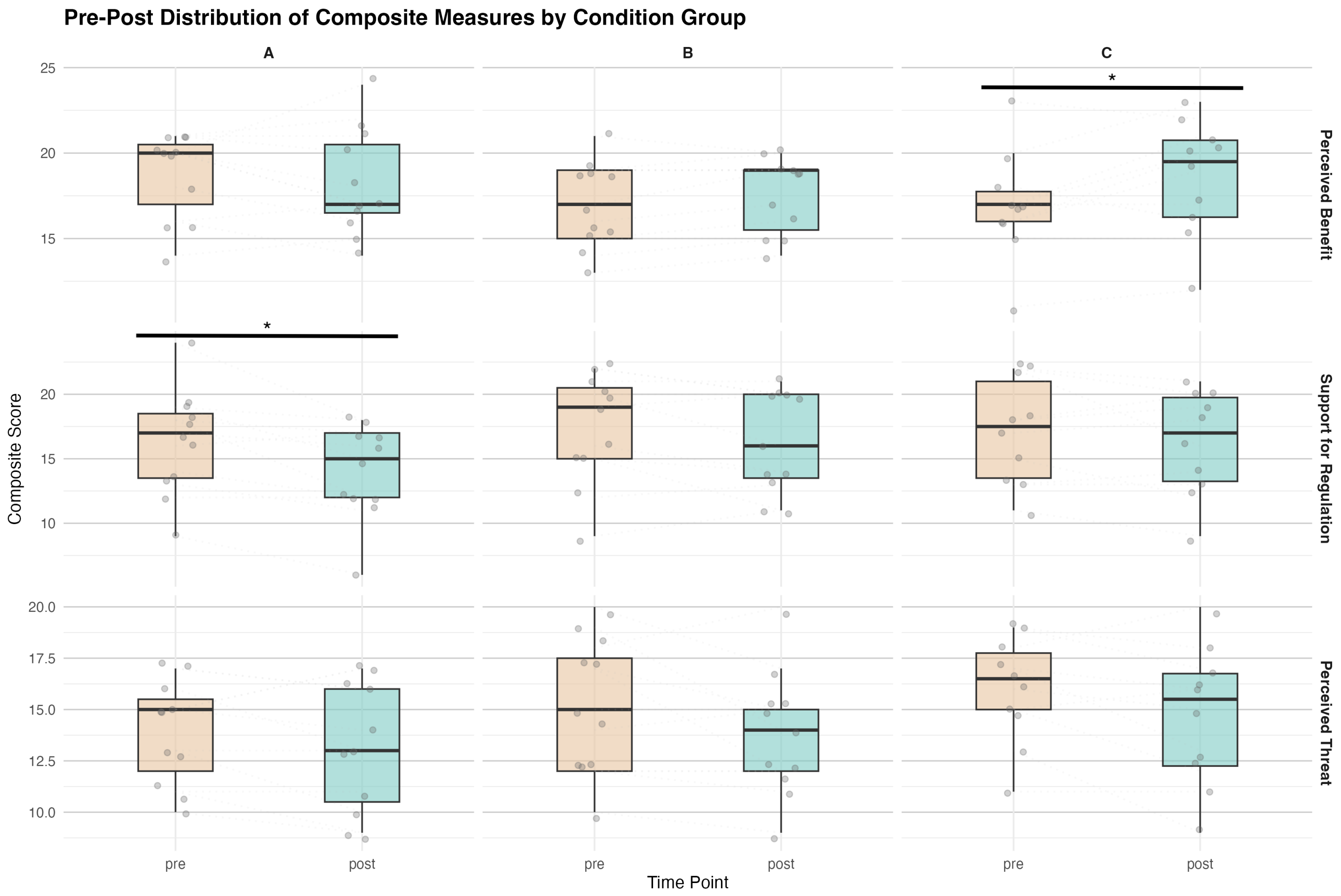

Figure 5: Pre- and post composite scores by information group.

C reported a significant increase in perceived benefits from pre (M = 17.0) to post (M = 18.5; Δ = +1.50, p = .014), while Group A remained stable (β = 0.55, p = .33) and Group B showed a non-significant trend toward increase (Δ = +0.55, p = .33). This suggests that manipulation in Group C effectively improved the recognition of societal advantages associated with autonomous trucks by participants.

Perceived Threats. The interaction effect of pre-post attitude response and different groups did not reach significance, but post-hoc within-group comparisons revealed meaningful reductions in threat perception for Group B (Δ = 1.27, p = .044) and Group C (Δ = 1.30, p = .049). Group A showed a smaller, non-significant decrease (Δ = 0.73, p = .24). These results suggest that exposure to the simulator experience generally reduced perceived risks related to safety and control, particularly among participants in Groups B and C.

Individual Analysis. We found 2 out of 18 attitude items showing statistical significance after Benjamini–Hochberg correction. *(1) Driver Take Over Autonomous Trucks:* We found a significant main effect of framing condition ($\beta = -0.55$, $SE = 0.18$, $p = 0.004$), indicating that participants overall decreased their belief that a person should be present in the AT to take over if necessary. Post-hoc comparisons revealed that this decline occurred primarily in Group A ($\beta = 0.545$, $SE = 0.18$, $p = 0.004$), while Groups B and C showed no significant change from pre- to post-survey (both p's > 0.05). Interaction effects were not significant, suggesting that information framing did not differentially affect this attitude across conditions. *(2) Autonomous Trucks on Highways Only:* We found a significant interaction effect between Group and change from pre- to post-survey ($\beta = 0.87$, $SE = 0.31$, $p = 0.008$), with Group C increasing support for highway-only restrictions while Group A decreased support. This indicates that the experimental manipulation produced opposing attitude trajectories depending on information framing.

As shown in Figure 6, these effects illustrate how framing conditions can shape specific aspects of regulatory and safety-related attitudes. Participants exposed to limited framing (Group A) reduced their perceived need for human oversight, while those receiving richer information (Group C) showed increased support for highway-only operation. Together, these findings suggest that information framing may subtly redirect participants' priorities—from immediate human control toward broader operational safeguards.

6. Conclusions

This ongoing study investigates how human drivers perceive and react to autonomous trucks (ATs) under controlled experimental conditions using a fixed-base driving simulator. Participants were exposed to highway driving scenarios featuring both autonomous and manually operated trucks, with framing videos varying in informational richness to test their influence on perception and affective response. Multimodal data—including behavioral, physiological, and attitudinal measures—were collected to capture drivers' cognitive, emotional, and behavioral adaptation to AT encounters.

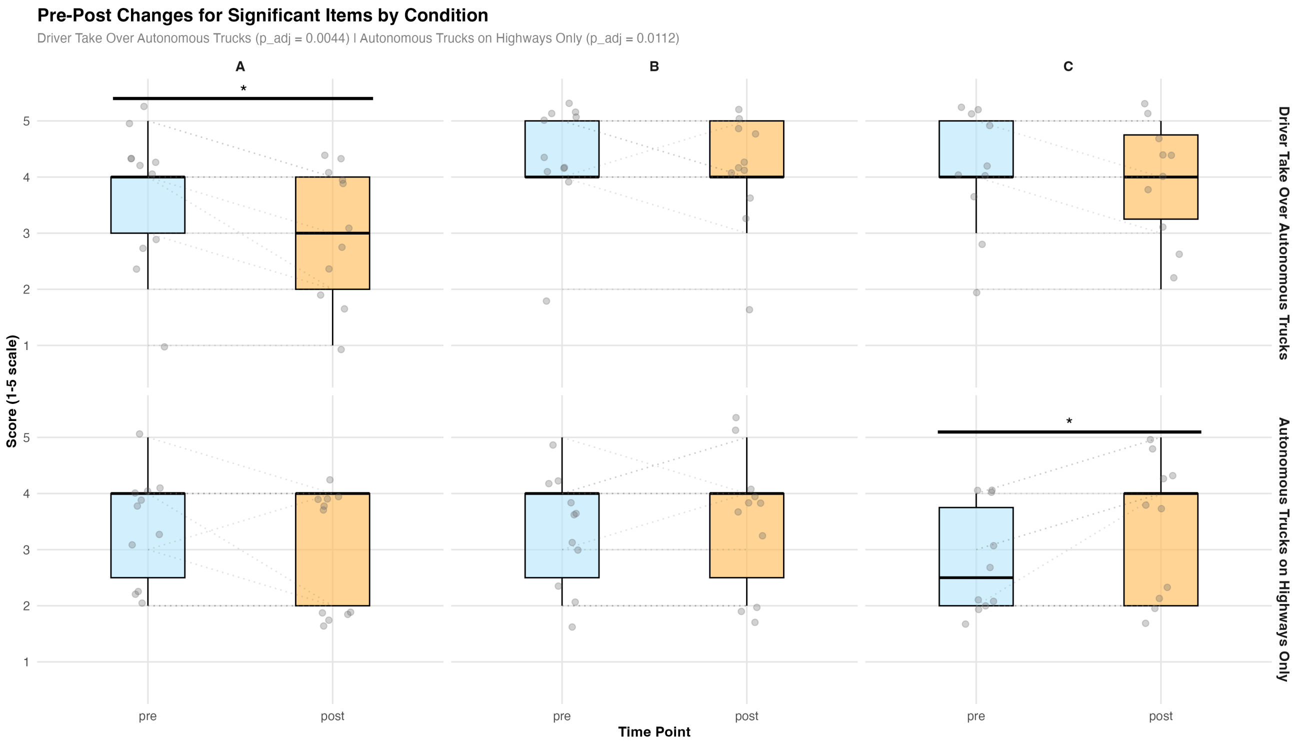

Figure 6: Pre–post changes for significant attitude items: **Driver Take Over Autonomous Trucks** and **Autonomous Trucks on Highways Only**, highlighting differences across information conditions (A, B, C).

Preliminary descriptive results suggest that exposure can increase acceptance of autonomous trucks, that drivers behave more cautiously around trucks (especially ATs), and that richer information framing may mitigate stress and vigilance responses. Attitudinal results indicate that perceived benefits outweigh perceived threats following exposure, while regulatory preferences show continued support for cautious oversight—particularly among those less accepting of automation.

Because data collection is still underway, these findings remain provisional. Future analyses with the full target sample will employ mixed-effects models to test these effects more rigorously, enabling stronger inferences about the mechanisms through which information framing and direct experience shape public acceptance. The final paper will report complete results and discuss implications for communication strategies, regulatory design, and deployment of autonomous trucking systems.

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