Comparing Driver Distraction in Touchscreen and Physical Vehicle Interfaces

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Over the past decade, in-car interface design has shifted dramatically from predominantly physical buttons and knobs to more screen-based and software-driven systems. Touchscreen dashboards and digital "infotainment" platforms now control a wide range of vehicle functions, from navigation and climate control to audio systems and safety features. While these interfaces offer flexibility, customizability, and visual interest, they also raise important questions regarding driver distraction. Unlike traditional physical controls, touchscreen systems often require sustained visual attention, precise touch targeting, and on-screen confirmations, all factors that may increase the amount of time drivers look away from the road.

Driver distraction remains a significant safety concern in transportation research and public policy. The U.S. National Highway Traffic Safety Administration (NHTSA) has established visual-manual distraction guidelines recommending that in-car tasks be designed such that single glances away from the roadway do not exceed two seconds and the cumulative glance time per task does not exceed 12 seconds. These thresholds provide an operational definition of "unsafe visual distraction," and serve as a benchmark for evaluating vehicle interface safety.

Despite growing public debate and regulatory attention surrounding touchscreen-heavy vehicle designs, direct comparisons between physical control interfaces and touchscreen-based interfaces remain limited. Much of the existing literature focuses solely on optimizing touchscreen systems or evaluating specific touchscreen tasks, rather than systematically comparing interface types under standardized conditions. As a result, questions remain about how the type of vehicle interface may influence measurable distraction, and how drivers perceive safety and usability across different vehicle interfaces.

This study seeks to address this gap by empirically comparing two types of common in-car interfaces: a physical control-based system and a touchscreen-operated system. Using objective glance-based distraction metrics aligned with NHTSA guidelines, alongside task performance and subjective self-reporting, this research aims to evaluate whether certain vehicle interface types are associated with increased visual distraction while completing common driving-related tasks, with the goal of contributing empirical evidence to ongoing discussions about safer vehicle interface design.

Ultimately, the findings of this study aim both to compare task performance and visual distraction across interface types and to inform design principles for reducing visual distraction in future vehicle systems.

Background and Related Work

Existing and Precedent In-Car Interface Systems

The evolution of in-car interfaces provides important context for understanding current debates around driver distraction. Early automotive navigation systems were significantly more limited in scope than today's infotainment environments; these GPS systems were designed primarily for route guidance rather than as a multifunctional vehicle control hub ("A Brief History of GPS In-Car Navigation," 2018; "Car Navigation History: From Rolled Paper Maps to CarPlay Connected Sygic App," 2018; "History of In-Car Navigation," n.d.). Interaction was restricted to physical buttons, directional pads, or rotary knobs, and destination entry was often expected to occur prior to driving. These prior systems treated driver attention as a scarce resource and limited in-motion interaction accordingly.

Modern infotainment systems represent a substantial shift from the original goals of in-car technology. Rather than functioning solely as navigation aids, contemporary systems operate as a centralized control module, integrating navigation, communication, media, vehicle settings, and more. Phone mirroring systems such as Apple CarPlay and Android Auto exemplify this shift; both systems project smartphone interfaces onto the vehicle display and aim to simplify interaction through voice control and familiar layouts (Crisara, 2025; Newcomb, 2025). These systems are often marketed and seen as distraction-reducing due to the simplified interface and integration of voice assistants (Ingalls, 2023).

At the same time, fully native touchscreen-centric systems, such as Tesla's interface design, concentrate nearly all vehicle interaction within a large central display, minimizing physical controls and relying heavily on visual confirmation for interaction (Budiu, 2019). While praised for their flexibility, innovation, and wide variety of features, touchscreen-dominant systems have also drawn criticism from safety and vehicle commentators due to the complexity of their design, the absence of tactile feedback, and the potential for extended eyes-off-road time ("Physical buttons outperform touchscreens in new cars," 2023; Sanchez, 2025; "Touchscreens Are Out, Buttons Are Back," 2025).

In response to growing safety and usability concerns, many manufacturers have recently reintroduced physical buttons or hybrid control systems. Industry reporting highlights companies such as Audi, Mazda, Volkswagen, and Mercedes shifting away from touchscreen-dominated interiors and reinstating dedicated tactile controls for frequently used or safety-critical functions (Golson, 2025; Kaneko, 2025; Priddle, 2025). These physical and hybrid systems attempt to balance the flexibility of touchscreen systems with the tactile affordances of physical systems, allowing drivers to rely on muscle memory rather than continuous visual monitoring ("Why cars still need physical HMIs: the case for mechanical switching in modern vehicles," 2025). Additionally, automotive journalists and designers have increasingly begun to advocate for a broader return to physical controls, arguing that touchscreen-dominant dashboards sacrifice safety and usability in favor of technological novelty (Scaff, 2025; Stevens, 2025).

This evolution of vehicle control systems from the once limited, tactile GPS systems to the slow integration of screen technology in vehicles, to the currently pervasive, fully touchscreen-dominant infotainment platforms, and back again toward hybrid designs reflects how assumptions about acceptable in-car interaction have changed and raises ongoing questions about the relationship between interface modality and driver distraction.

Policy and Regulatory Context

Recent developments in safety recommendations and regulations further highlight the relevance of studying in-car interface distraction. In the United States, the NHTSA issued voluntary Visual-Manual Driver Distraction Guidelines that recommend limiting single glances away from the roadway to approximately two seconds during a task, and cumulative off-road glance time during a task to approximately 12 seconds ("NHTSA Distraction Guidelines Initial Notice," n.d.; "Visual-Manual NHTSA Driver Distraction Guidelines for In-Vehicle Electronic Devices," 2013). These guidelines have become widely cited benchmarks for evaluating interface safety and distraction risk.

In Europe, Euro NCAP announced that beginning with 2026 testing protocols, any vehicle seeking a high safety rating must provide physical controls for five key safety-critical features: indicating directions, triggering hazard lights, sounding the horn, operating windscreen wipers, and activating an SOS function that automatically calls emergency services in the event of a serious collision ("Cars will need buttons not just touchscreens to get a 5-star Euro NCAP safety rating," 2024; Hellen, 2024). Though Euro NCAP ratings are not legislative mandates and therefore not mandatory for vehicles to implement, they significantly influence manufacturer design decisions and signal growing institutional and customer concerns regarding the safety of in-vehicle touchscreens (White, 2024).

Additionally, the broader United Nations Economic Commission for Europe (UNECE) safety governance ecosystem increasingly emphasizes driver engagement and safe in-vehicle interaction models through specific regulations such as UN Regulation No. 79, which covers steering and assistance systems, and the general WP.29 regulations, which center around driver control, engagement, and human-machine interface expectations ("Addendum 78: UN Regulation No. 79," 2023; "New UN regulation paves the way for the roll-out of additional driver assistance systems," 2024). While these regulations are not specific to touchscreens, they do indicate a broader tightening of expectations around driver attention, safety, and in-car human-machine interaction.

These policies and the current public discourse around them signal that norms are changing; reputable automotive and safety coverage media have increasingly begun to frame the touchscreen trend as a safety and usability issue, rather than a simple design trend. Attitudes have clearly shifted after the oversaturation of touchscreens in vehicles: customers and automotive manufacturers alike, who initially embraced these efforts of "modernization," are now growing frustrated with these often unreliable systems and concerned about their potential safety risks, leading to formal regulatory responses such as the NHTSA Visual-Manual Driver Distraction Guidelines and Euro NCAP's new testing protocols. The growing desire for and reintroduction of physical controls suggest that widespread assumptions about acceptable levels of visual demand required by vehicle control interfaces are evolving away from technology overreliance (Nicholson-Messmer, 2025).

Relevant Literature

From a safety standpoint, driver distraction has long been a subject of concern. The proliferation of cheap commoditized touchscreens has made this modality an attractive choice for in-car interfaces (Posky, 2022). However, compared to physical control-operated vehicle interfaces, touchscreens involve significant tradeoffs: while they are cheap to produce and easy to deploy, they do not allow for tactile exploration or discovery, forcing drivers to turn their heads to utilize the screen's functions. This also reduces drivers' ability to develop muscle memory for their in-car systems (Farooq et al., 2019).

Farooq, Evreinov, and Raisamo (2019) further note that the relatively long development and quality control cycles in the automotive industry have generally ensured gradual progress without significant regressions. However, the rapid advancement of mobile computing over the last 15 years has put pressure on automakers to move quickly in order to avoid being left behind, and has also introduced new low-cost alternatives to many traditional car systems. Farooq, Evreinov, and Raisamo argue that, to properly account for potential safety issues, the automotive industry must devote greater attention to the design and research of in-vehicle systems.

Capturing useful driver distraction-related data can be challenging, as any study conducted in normal on-road conditions introduces uncontrollable variables and issues of potential researcher liability. To mitigate this risk, studies on the effects of driver distraction and in-car control systems have employed various methodologies, including the use of driving simulators (Grahn & Kujala, 2020; Khanh, 2022; Mullenbach, 2013), closed-course track testing

(Ferris et al., 2016), and subjective workload surveys (Khanh, 2022). These studies have identified dependent variables such as eyes-off-road time, glance duration, and responses to roadside hazards. While driving a real car on a closed course provides the highest level of realism short of real-world driving, this approach is often expensive and resource-intensive. Driving simulators dramatically reduce the cost and complexity of executing such a study, but they may also reduce ecological validity. Identifying an appropriate methodology that balances ease of implementation and accessibility with data reliability is an essential part of any study in this area.

Translating design patterns developed for mobile devices into forms suitable for the automotive environment is an important task in the development of effective in-car interfaces. As Grahn and Kujala (2020) found, when applications were designed specifically for automotive installations, visual demand and distraction were lower than for applications designed for smartphones or mobile devices. While the interaction model between a user and a mobile device may appear similar to that of an in-car interface, this study clarifies that context significantly changes the design requirements of an interface. Grahn and Kujala concluded that the number of visual or visual/manual interaction steps required during a single glance increased the duration of the glance, thereby increasing its visual distraction potential. To refine their understanding of the design requirements for in-car touchscreen systems, Lasch and Kujala (2012) tested various methods of operating a touchscreen in an in-car environment; they found that swiping, rather than buttons or kinetic scrolling, minimized distraction, and that a maximum of five items per screen was ideal. These findings further reinforce the need to consider the design contexts of in-car applications as distinct from those of mobile or desktop applications.

The role of haptic and auditory cues also plays an important role in driver-vehicle interaction. Ferris, Suh, and Miles (2016) found that the lack of both auditory and vibro-tactile feedback in touchscreen interactions led to a significant degradation in input task performance, compared to the natural haptic feedback provided by physical controls or touchscreen interfaces equipped with synthetic feedback. Mullenbach (2013) further explored the concept of haptics by introducing programmable physics-based cues within a visual display using a variable-function touchpad.

These prior works describe many of the deficiencies of touchscreen interfaces and suggest that haptics and physical interaction capabilities may improve interaction performance and reduce driver distraction. However, few studies directly compare the visual attention required to interact with physical controls versus virtual touchscreen controls. The present study aims to address this gap by quantifying and comparing participants' eyes-off-road time when interacting with physical controls and touchscreen interfaces.

Research Questions and Hypotheses

Building on prior research that suggests that interaction modality and tactile feedback influence visual demand, this study seeks to answer the following questions:

1. Do drivers using touchscreen-operated vehicle interfaces and physical control-operated interfaces differ in their levels of visual distraction when completing common and necessary in-car driving tasks?

In this study, "visual distraction" is defined using the NHTSA visual-manual distraction guidelines: when completing an in-vehicle task, single glances should not exceed two seconds, and cumulative off-road glance time should not exceed 12 seconds.

2. How do perceived safety, usability, and confidence differ between touchscreen and physical control interfaces, and how do these subjective perceptions relate to observed distraction outcomes?

Based on prior findings regarding tactile affordances and memory, visual demand, and interaction complexity, the following hypotheses were formulated:

1. Participants using a physical control interface will exhibit lower levels of visual distraction than participants using a touchscreen interface. Specifically, participants in the touchscreen condition are expected to demonstrate:
   - Longer average single-glance durations,
   - A greater number of single glances exceeding two seconds,
   - Higher cumulative glance times per task, and
   - A greater proportion of tasks exceeding the 12-second cumulative glance threshold.

This hypothesis is grounded in research suggesting that the lack of tactile feedback in touchscreen systems necessitates sustained visual attention and visible confirmations during interaction.

2. Participants using a physical control interface will report higher perceived safety, usability, and confidence compared to participants using a touchscreen interface.

This hypothesis also reflects prior research covering tactile memory and visual demand, which indicates that tactile controls enhance perceived ease of use during interaction and task completion.

Methodology

Study Design Overview

This study employed a between-subjects design, in which participants were grouped based on the type of interface present in their vehicle: physical or touchscreen-based. Each participant completed the study in their own vehicle to ensure consistent familiarity with the interface.

Each participant completed a single testing session consisting of a series of standardized in-car tasks, performed while maintaining attention on a forward-facing visual stimulus. Objective and subjective measures were collected during and after task completion.

Participants

Participants were recruited from the general population near Drexel University in Philadelphia, PA, as well as from the San Jose, CA area, where one of the researchers is based. Recruitment methods included outreach to friends and family, in a manner designed to avoid any conflicts of interest. Testing responsibilities were divided between the researchers based on location: the physical control sessions were conducted in the Philadelphia area, while the touchscreen sessions were conducted in the San Jose area.

In order to participate in the study, participants had to meet the following criteria:

- Possesses a valid driver’s license
- Drives the vehicle used in the study session regularly (for the purposes of this study, “regularly” is defined as use ranging from daily to at least a few times per month)
- Is generally familiar with their vehicle’s interface

Individuals who were unable to complete visual, verbal, or physical in-car tasks or who had insufficient driving experience were excluded from this study. A total of four participants were included, with two participants per interface category.

Interface Tasks

Participants were instructed to complete a series of both essential and nonessential driving-related tasks using their vehicle's dashboard controls. These tasks were selected because they are available in both types of interfaces being tested, they represent functions that may need to be used while driving, and they vary in their required visual and tactile interaction.

The assigned in-vehicle tasks for both interfaces were:

1. Adjust the temperature
2. Activate the defroster or defogger
3. Adjust the volume
4. Activate and adjust the windshield wipers
5. Activate the headlights
6. Activate the seat heater

Note that although the touchscreen vehicle included physical controls on the steering wheel for some of the above tasks, participants in that condition were instructed not to use them and to complete the study tasks using the touchscreen interface only, in order to isolate touchscreen-based interaction for comparison with physical control-based interaction.

Secondary Visual Attention Task

To simulate the need for sustained forward visual attention while driving, participants were presented with a high-contrast visual stimulus consisting of clearly distinguishable numbers presented at random intervals. Participants were instructed to identify these numbers aloud while completing in-car tasks.

This high-contrast visual stimulus was chosen as it encouraged participants to maintain a consistent forward gaze and provided a standardized visual anchor from which gaze deviation could be measured. Time spent looking away from the visual stimulus was recorded and used to quantify distraction.

Measures

Objective Distraction Metrics

Distraction was operationalized using the NHTSA visual-manual distraction thresholds, and in accordance with these guidelines, single glances exceeding two seconds and a cumulative off-road glance time exceeding 12 seconds per task were treated as indicators of elevated visual distraction. A "glance" was defined as the participant's eyes leaving the forward visual stimulus for at least 0.25 seconds.

From the coded video data, the following objective distraction metrics were derived:

- Glance-Level Metrics
  - Total number of single glance deviations
  - Total number of single glance deviations exceeding two seconds
  - Percentage of single glances exceeding two seconds
  - Average single-glance deviation duration
  - Longest single-glance deviation duration
- Task-Level Glance Metrics
  - Task(s) with the most single-glance deviations

    - Task(s) with the most single-glance deviations exceeding two seconds
    - Average single-glance duration per task
    - Longest single-glance duration per task
    - Cumulative glance time per task
    - Task(s) exceeding the 12-second cumulative threshold
    - Percentage of tasks exceeding 12 seconds
    - Task(s) with the highest cumulative glance duration
- Participant-Level Distraction Metrics
    - Total cumulative glance time across all tasks

In addition to glance behavior, observable hesitation or corrective behaviors were also considered as behavioral indicators of interaction difficulty.

Performance Metrics

To evaluate interface efficiency and task performance, the following performance metrics were collected:

- Completion time per task
- Total completion time across all tasks
- Total number of failures per task
- Cumulative hesitation/correction time per task
- Task(s) associated with the longest hesitation period

Subjective User Experience Measures

Following task completion, participants responded to a structured questionnaire including both Likert-scale and open-ended items. The Likert-scale questions, on a scale of 1-5 or Strongly Disagree to Strongly Agree, asked participants to reflect on the following measures:

- Perceived Difficulty
    - Ease of use
    - Intuitiveness of task steps
- Perceived Confidence & Attention
    - Confidence while focusing on the visual attention task
    - Perceived visual demand
- Safety
    - Comfort and safety when using the interface while driving

The open-ended measures provided participants an opportunity to reflect openly on their experiences, particularly:

- Tasks that felt easiest and most difficult
- Moments of perceived distraction
- Interface strengths and weaknesses
- Design improvement suggestions
- Perceived safety of different interface types

These qualitative responses were used to contextualize objective distraction findings and identify any perceived usability or safety tradeoffs.

Data Collection Procedure

Two cameras were used during each session, one capturing dashboard interactions and one capturing participants' faces and eye movements, and audio was recorded to capture verbal responses and task-related commentary. The researcher was present in the vehicle during testing and recorded any additional observational notes. Video recordings were then later manually coded to extract glance start and end times, task start and end times, and hesitation or correction incidents, from which the total number of NHTSA threshold violations could be calculated.

Results

Overview

This section presents the results of the study and compares the physical control-operated and touchscreen-operated vehicle interfaces across both objective performance metrics and subjective participant responses. The results are organized into several categories that reflect the different types of data collected during the study. First, objective measures of driver distraction were analyzed using the glance-based metrics derived from NHTSA visual-manual distraction guidelines. Next, task performance outcomes were examined, including task completion times, failure rates, and overall execution patterns. Observable hesitation and correction behaviors recorded during the study were also analyzed to identify moments where participants appeared uncertain or struggled with specific interactions. Lastly, subjective participant responses gathered through post-task questionnaires and open-ended questions were examined to understand participants' perceptions of usability, safety, and attention demands across the two interface types.

Across nearly all objective metrics, the touchscreen interface was associated with substantially greater levels of visual distraction and longer task completion times than the physical control interface. Participants using the touchscreen-operated vehicle exhibited more frequent glance deviations, a higher number of glances exceeding the NHTSA two-second threshold, higher cumulative glance times across tasks and per task, and significantly longer overall task completion times. Subjective participant responses largely reflected these trends, with participants using the touchscreen interface reporting greater visual demand and lower perceived safety compared to participants using the physical control interface.

Objective Distraction Outcomes

Total Glance Frequency and Long-Glance Violations

Significant differences were observed between the physical control and touchscreen interfaces in measures of glance frequency and glance duration. Touchscreen participants averaged 32 total glance deviations, whereas physical control participants averaged 11.5 total glance deviations, meaning that, on average, participants using the touchscreen interface exhibited 20.5 more glance deviations away from the visual task compared to participants using the physical control interface.

Differences were also observed in the frequency of glances exceeding the two-second threshold recommended by the NHTSA. Participants using the physical control interface averaged 1 glance exceeding two seconds, whereas touchscreen participants averaged 12 such glances, showing an increase of 11 long glances in the touchscreen condition. As a result, the percentage of glances exceeding two seconds was substantially higher for the touchscreen interface at approximately 37.3%, compared to the physical interface at approximately 10.03%, showing an increase of approximately 27.27%.

Average glance duration also differed between the two interfaces. Participants using the physical interface exhibited an average single-glance deviation time of 1.4 seconds, whereas touchscreen participants averaged approximately 3.02 seconds per glance, representing an increase of approximately 1.62 seconds. The longest single glance recorded in the touchscreen condition was 14.5 seconds, 11 seconds higher than the longest glance recorded for the physical control condition, which was 3.5 seconds. Together, these findings indicate that touchscreen participants not only looked away from the visual task more frequently, but also tended to maintain longer individual glances away from the visual attention task when interacting with the interface.

Cumulative Glance Time

In addition to individual glance behavior, cumulative glance time across tasks was substantially higher for the touchscreen interface. Participants using the physical control vehicle accumulated an average of 15.25 seconds of total gaze deviation time across all tasks, whereas touchscreen participants accumulated 95 seconds, showing a difference of 79.75 additional seconds of "eyes-off-task" time in the touchscreen condition.

Further differences emerged when examining the NHTSA-recommended cumulative glance threshold of 12 seconds per task. None of the tasks performed using the physical control interface exceeded this threshold, but in contrast, approximately 42.9% of tasks performed using the touchscreen interface exceeded the 12-second cumulative glance threshold. Specifically, the volume adjustment, windshield wiper activation, headlight activation, and seat heater activation tasks each exceeded the cumulative threshold in the touchscreen condition.

NHTSA Threshold Exceedance

When considering both types of NHTSA guideline violations, single glances exceeding two seconds and cumulative task glance times exceeding 12 seconds, the touchscreen interface produced substantially more violations overall. Participants using the physical interface recorded 1 total NHTSA violation due to a single glance exceeding two seconds, and no tasks exceeded the 12-second cumulative threshold. In contrast, participants using the touchscreen interface recorded 15 total violations, consisting of an average of 12 single glances exceeding two seconds and three tasks exceeding the 12-second cumulative glance threshold.

Overall, the touchscreen interface produced 14 more NHTSA guideline violations than the physical control interface. None of the tasks completed using the physical interface exceeded the 12-second cumulative threshold, whereas nearly half of the tasks completed using the touchscreen interface did, indicating a substantially higher level of visual distraction associated with the touchscreen condition.

Task-Specific Performance Patterns

Consistently Problematic Tasks

Task-level analysis revealed several differences in how participants interacted with the two interface types. In the physical interface condition, the tasks associated with the greatest amount of glance activity, including glances exceeding two seconds, were temperature adjustment and defroster/defogger activation. In contrast, in the touchscreen interface condition, the tasks associated with the highest number of glance deviations were temperature adjustment and seat heater activation, while the tasks producing the greatest number of glances exceeding two seconds were volume adjustment, windshield wiper activation, and seat heater activation.

Among all the tasks tested, windshield wiper activation emerged as the most demanding interaction in the touchscreen interface condition. This task produced a cumulative glance time of 28.25 seconds, compared to 1 second for the physical interface. The average single-glance duration during this task was approximately 6.42 seconds for the touchscreen interface, compared to 0.35 seconds for the physical interface. The longest single glance recorded during this task was 14.5 seconds in the touchscreen condition, compared to 0.5 seconds in the physical condition. Additionally, this task also produced the longest cumulative gaze deviation time for both touchscreen participants, further indicating that the touchscreen implementation of this control imposed substantial visual demand.

Headlight activation also required significantly more visual attention in the touchscreen condition. The cumulative glance time for this task was 15.5 seconds for the touchscreen interface, compared to 1.5 seconds for the physical interface. The average single-glance duration was approximately 6.67 seconds for the touchscreen interface, compared to 0.75 seconds for the physical interface, and the longest single glance was 10 seconds in the touchscreen condition, compared to 1 second in the physical condition.

Similar patterns were observed for volume adjustment and seat heater activation, both of which showed substantially higher distraction in the touchscreen interface condition. For volume adjustment, cumulative glance time was 12.75 seconds in the touchscreen condition, compared to 0.75 seconds for the physical condition. The average single-glance duration for this task was approximately 2.98 seconds for the touchscreen interface, compared to 0.5 seconds for the physical interface, and the longest single glance was 6 seconds, compared to 0.5 seconds for the physical interface. Seat heater activation also produced increased visual demand in the touchscreen interface: cumulative glance time reached 13.5 seconds, compared to 2 seconds for the physical interface, while the longest single glance was 5 seconds, compared to 1.5 seconds for the physical interface.

Within the physical interface condition, temperature adjustment and defroster/defogger activation appeared somewhat more attention-demanding than other tasks. For participants using the physical interface, these tasks produced the greatest number of single-glance deviations, including glances exceeding two seconds, and the longest cumulative gaze deviation times. Defroster/defogger activation produced the highest cumulative glance time of all tasks at 4.75 seconds, the highest average single-glance duration at 1.95 seconds, and the longest single glance at 3 seconds. Temperature adjustment resulted in the second-highest cumulative glance time of 3.5 seconds, the second-highest average single-glance duration of 1.75 seconds, and the second-longest single glance of 2.5 seconds.

Task Completion Times and Failures

In addition to differences in glance behavior, clear differences were observed in overall task performance. Participants using the touchscreen interface required substantially more time to complete the set of study tasks. The total completion time across all tasks averaged 31.5 seconds for the physical interface compared to 87 seconds for the touchscreen interface, with a difference of 55.5 additional seconds in the touchscreen condition.

Several tasks exhibited particularly large differences in completion time. Temperature adjustment required 15 seconds in the touchscreen condition, compared to 5 seconds in the physical condition. Volume adjustment required 13 seconds in the touchscreen condition, compared to 2.5 seconds in the physical condition. Windshield wiper activation required 24 seconds in the touchscreen condition, compared to 2.5 seconds in the physical condition. Headlight activation required 10 seconds in the touchscreen condition compared to 4 seconds in the physical condition, and seat heater activation required 13.5 seconds in the touchscreen condition compared to 4 seconds in the physical condition.

Task failures were also more common in the touchscreen condition. Failures in the physical interface condition were minimal, with the only average nonzero failure value of 0.5 occurring during the windshield wiper adjustment task, indicating that one participant using the physical interface experienced a failure during this task. In contrast, participants using the touchscreen interface exhibited failures during defroster/defogger activation, volume adjustment, windshield wiper activation, and seat heater activation.

Taken together, these results indicate that the touchscreen interface condition was associated with increased visual distraction, slower task execution, and a higher number of task failures compared to the physical control interface.

Observable Hesitation and Correction Behaviors

Alongside the quantitative distraction and performance metrics, observable hesitation and correction behaviors were recorded during the study to identify moments in which participants appeared uncertain or required additional effort to complete a task. These behaviors typically involved pauses, repeated attempts to locate a control, or visible corrections after an initial incorrect interaction.

In the physical interface condition, hesitation and correction behaviors were relatively limited and distributed across several different tasks, rather than concentrated around a single specific interaction. The tasks in which these behaviors were observed included defroster/defogger activation, volume adjustment, windshield wiper adjustment, headlight activation, and seat heater activation. These issues did not consistently occur across both participants for the same task, suggesting that moments of hesitation in the physical condition were more sporadic and likely related to individual unfamiliarity with specific controls, rather than any systematic interface difficulties.

In contrast, hesitation and correction behaviors in the touchscreen interface condition were more clearly concentrated around a smaller set of tasks. In particular, windshield wiper activation consistently produced significant hesitation for both touchscreen participants. For this task, one participant exhibited a cumulative incident time of 18 seconds, with the other exhibiting a cumulative incident time of 21 seconds, indicating that both participants spent extended periods of time attempting to locate or correctly activate this control. This pattern reinforces the quantitative results that show that windshield wiper activation imposed the greatest visual demand in the touchscreen condition.

Additional hesitation behaviors in the touchscreen condition were also observed during volume adjustment and seat heater activation, though these occurred for only one participant in each case. Regardless, these tasks still contributed to the overall increase in interaction difficulty observed for the touchscreen interface.

Further analysis of hesitation patterns revealed that both touchscreen participants experienced their longest period of observable hesitation during the windshield wiper activation task, and this task also produced the most severe individual moment of hesitation or correction for both participants. In contrast, the physical interface participants' longest and most severe hesitation moments were more distributed across tasks, particularly defroster/defogger activation, windshield wiper adjustment, volume adjustment, and headlight activation, and these instances occurred for only one participant each.

These observations suggest that hesitation behaviors in the touchscreen condition were more task-specific and systematic, whereas hesitation behaviors in the physical control condition were less severe and more evenly distributed across tasks.

Subjective Ratings and Responses

Likert-Scale Results

Participants' Likert-scale responses revealed clear differences in perceived usability, visual demand, confidence, and safety between the two interface types. In the physical interface condition, participants were neutral on ease of use, with both participants selecting a rating of 3, and perceived intuitiveness slightly negatively, with both participants selecting a rating of 2. Additionally, participants reported relatively low visual demand, with ratings of 2 and 3 for this measure, though they also expressed low confidence in completing interface tasks while maintaining the secondary visual task, again with ratings of 2 and 3 for this measure. However, despite these mixed usability perceptions, participants reported high feelings of safety when using the interface while driving, assigning ratings of 5 and 4.

In contrast, participants in the touchscreen interface condition reported consistently more negative perceptions across all measured categories. Both participants disagreed that the interface was easy to use, assigning ratings of 2, and reported very low confidence when attempting to complete interface tasks while maintaining the secondary visual task, with ratings of 1 and 2. Participants also reported high perceived visual demand, assigning ratings of 4 and 5, and low perceived safety, with both participants assigning a rating of 2.

These subjective ratings closely reflected the patterns observed in the objective distraction metrics. Participants using the touchscreen interface reported greater visual demand, lower confidence, lower perceived ease of use, and lower perceived safety than participants using the physical control interface.

Open-Ended Patterns

Participants' open-ended responses provided additional context for these ratings and revealed several recurring themes. In the physical interface condition, participants generally described the interface as manageable but not without flaws, with the most commonly mentioned difficulties involving defroster/defogger activation and windshield wiper adjustment. One participant specifically noted that the placement of the defroster/defogger controls in their vehicle required them to look down and visually search for the buttons, suggesting that the location of certain controls influenced interaction difficulty, even within the physical interface condition.

Participants in the touchscreen interface condition, by contrast, frequently described the interface as visually demanding and frustrating to use. Several tasks were repeatedly identified as particularly distracting, including volume adjustment, headlight activation, and windshield wiper activation. These responses align closely with the quantitative results, which showed that these same tasks produced some of the highest cumulative glance times and longest individual glance durations in the touchscreen condition. One participant additionally noted that nearly all the interface tasks required looking away from the visual attention task for longer than they would have preferred, further demonstrating the perception of increased visual demand associated with the touchscreen interface.

Participant Interface Preferences and Design Suggestions

Participants were asked several questions regarding their overall interface preferences and suggestions for potential improvements to the interface design of their vehicle. Across both conditions, responses revealed a consistent pattern of participants favoring physical controls or hybrid interface designs over touchscreen-only systems.

When asked which type of interface they would prefer in a vehicle, no participant selected a fully touchscreen-only interface: participants in the physical interface condition indicated a preference for either entirely physical controls or hybrid systems that integrate touchscreen functionality with physical controls, while both participants in the touchscreen interface condition also expressed a preference for hybrid systems.

Participants were also asked which type of vehicle interface they believed to be the safest to use while actively driving, and their responses followed a similar pattern, with participants from both groups selecting either entirely physical interfaces or hybrid systems. Once again, no participant believed a fully touchscreen-based interface to be the safest design.

The touchscreen participants provided several specific design suggestions that they believed would reduce distraction and improve usability: these included more physical or steering-wheel-mounted controls for frequently used functions, voice-control capabilities, and improved screen placement to reduce the amount of time required to visually locate interface elements on the center console screen.

On the other hand, participants in the physical interface condition acknowledged that physical controls were not always ideal in every situation. One participant suggested that the defroster/defogger activation task might have been easier to operate through a touchscreen interface, as the relevant controls and information would likely be centralized visually in a single location. The other participant also indicated that voice control capabilities could improve interaction, regardless of interface type.

Overall, participants across both interface conditions tended to favor hybrid or physical control-heavy interface designs, suggesting a general preference for systems that combine the tactile advantages of physical controls with the flexibility of digital interfaces, rather than systems that rely exclusively on touchscreen interaction.

Results Summary

Across nearly all objective distraction and performance metrics, the touchscreen interface produced substantially higher levels of visual demand than the physical control interface. Participants using the touchscreen vehicle exhibited more frequent glance deviations, a higher number of glances exceeding the NHTSA two-second threshold, greater cumulative glance times across tasks and per tasks, and a significantly higher number of overall NHTSA guideline violations. The touchscreen interface was also associated with slower task completion times, a higher number of task failures, and more pronounced hesitation and correction behaviors during task execution.

Participants' qualitative responses largely reinforced these objective findings. Participants using the touchscreen interface reported lower perceived usability and intuitiveness, higher perceived visual demand, lower confidence in completing tasks while maintaining attention on the visual task, and lower perceived safety when interacting with the interface while driving.

Task-level analysis further revealed that several task interactions were particularly problematic in the touchscreen condition. Windshield wiper activation, headlight activation, seat heater activation, and volume adjustment produced the highest cumulative glance times, longest individual glances, and the most noticeable hesitation behaviors. In contrast, while the physical interface generally produced lower distraction levels, defroster/defogger activation and windshield wiper adjustment emerged as the primary sources of interaction difficulty for participants in that condition.

The results consistently indicate that the touchscreen interface required more visual attention, longer interaction times, and greater effort to complete common vehicle-control tasks than the physical control interface. These findings provide a foundation for interpreting the causes of these differences and evaluating the implications of interface design choices, which are explored in the following section.

Discussion

Overview

This study compared touchscreen-based and physical control vehicle interfaces in terms of driver distraction, task completion performance, and participants' perceived usability and safety. The results revealed substantial differences between the two interface types across both objective performance metrics and subjective participant responses.

Across nearly all objective measures, the touchscreen interface produced higher levels of visual distraction than the physical control interface. Participants using the touchscreen vehicle exhibited more frequent glance deviations away from the secondary visual attention task, a higher number of glances exceeding the two-second threshold recommended by the NHTSA, and higher cumulative glance times across tasks, patterns that resulted in substantially more total NHTSA guideline violations for this condition. In addition to these distraction metrics, touchscreen participants demonstrated longer overall task completion times and exhibited greater hesitation and correction behaviors during interface interaction.

Participants' subjective responses closely reflected these objective findings. Touchscreen participants reported lower perceived usability, intuitiveness, confidence, and safety, and higher perceived visual demand. The alignment between the objective distraction metrics and the subjective participant perceptions suggests that the touchscreen interface imposed a greater visual and interaction burden on drivers than the physical control interface.

Interpretation of Objective Distraction Outcomes

One of the most immediate differences between the two interface conditions was the frequency with which participants looked away from the secondary visual task. On average, participants using the touchscreen interface exhibited a substantially higher glance frequency than those using the physical control interface, indicating that they needed to redirect their visual attention away from the visual task more often in order to complete the required interactions.

One explanation for this pattern is that touchscreen interfaces require drivers to visually search for interface elements before interacting with them. Because touchscreen controls lack tactile cues, drivers cannot rely on physical feedback to locate controls and therefore have to divert their gaze to view them. As a result, participants often needed to visually identify and confirm the correct icon or menu option before making a selection. In contrast, physical controls allow drivers to locate buttons, knobs, or switches through tactile feedback, enabling users to rely on muscle memory once they become familiar with the placement of controls. This tactile discoverability reduces the need for visual confirmation and therefore decreases the frequency of glance deviations.

In addition to this, touchscreen participants also exhibited substantially longer glance durations. Several individual glances in the touchscreen condition were significantly longer than those observed in the physical control condition, including some extreme cases where participants maintained visual attention on the interface for extended periods. These longer glances likely occurred because touchscreen interactions often required participants to navigate menus, identify icons, and visually confirm selections before completing a task. Physical controls, by contrast, generally require fewer and simpler interaction steps and allow drivers to complete tasks more quickly, enabling them to return their visual attention to the roadway sooner.

These longer glances are particularly important when considering the NHTSA visual-manual distraction guidelines, which recommend limiting individual glances away from the roadway to two seconds. Many of the glances observed in the touchscreen condition exceeded this threshold, indicating a higher potential for driver distraction.

Lastly, touchscreen participants accumulated substantially higher cumulative glance times across tasks. Even when individual glances were relatively short, repeated interactions with the touchscreen interface resulted in a much larger total amount of time spent looking away from the visual task. This effect is likely related to the multi-step nature of many touchscreen interactions, which often require several visual confirmations before a task can be completed.

When evaluated against the NHTSA guideline recommending that cumulative off-road glance time during a task remain below 12 seconds, the differences between the two interface conditions become clear. Nearly half of the tasks performed using the touchscreen interface exceeded this cumulative threshold, whereas none of the tasks performed using the physical control interface did. This pattern suggests that touchscreen-based vehicle interfaces may significantly increase the overall visual demand placed on drivers during routine and essential interactions.

Task-Level Differences

While the overall results indicate that the touchscreen interface produced greater levels of distraction across nearly all metrics, examining the results at the task level provides additional insight into why certain interactions seemed to be particularly problematic.

Among all tasks tested, windshield wiper activation produced the most severe distraction in the touchscreen condition. One possible explanation for this pattern is that drivers typically expect windshield wipers to be controlled through a lever or stalk located near the steering wheel, which allows for quick and easy activation and does not require visual attention. Therefore, relocating this function to a touchscreen may disrupt drivers' existing mental models and learned interaction patterns. Instead of relying on familiar tactile controls, participants were required to visually search the interface, locate the correct control, and complete the task through multiple interaction steps. The complexity of this interaction likely contributed to the significantly higher levels of distraction observed for this task.

Headlight activation and volume adjustment also produced relatively high levels of distraction in the touchscreen condition. These functions are typically implemented as immediately accessible physical controls in most vehicles, allowing drivers to make quick adjustments through rapid tactile interaction and muscle memory. However, when these interactions are moved to a touchscreen interface, drivers must first visually locate the appropriate control before interacting with it, and in many cases, this process also involves navigating menus or visually confirming selections, which increases both the number and duration of glance deviations.

Although the physical interface generally produced lower distraction levels overall, the results also indicate that not all physical controls were automatically intuitive. In the physical control condition, tasks such as defroster/defogger activation and windshield wiper adjustment still produced moments of hesitation and longer glance durations compared to the other physical control tasks. This suggests that physical interfaces can still induce distraction when controls are poorly placed, difficult to locate, or insufficiently labeled. While physical controls may reduce visual demand compared to touchscreen interfaces, effective control placement and interface design remain important factors in minimizing driver distraction.

Relationship Between Objective and Subjective Data

Participants' subjective perceptions of the interfaces closely mirrored the patterns observed through the objective distraction metrics. In the touchscreen condition, participants frequently reported needing to look away from the visual task for longer than they would have preferred, experiencing difficulty completing certain interactions, and feeling unsafe at the idea of performing these tasks while maintaining attention on the road. These perceptions correspond closely with the quantitative findings of the touchscreen condition, which showed substantially higher glance frequencies, longer individual glances, higher cumulative glance times, and a significantly greater number of NHTSA guideline violations.

In contrast, participants in the physical interface condition reported feeling relatively safe when interacting with the vehicle controls and perceived the interface as requiring less visual attention. These perceptions align with the objective results, which demonstrated fewer glance deviations, shorter glance durations, and faster task completion times in the physical control condition.

The close alignment between subjective participant responses and objective distraction metrics strengthens confidence in the findings of this study. This consistency suggests that participants were largely aware of the visual demands imposed by the interfaces, and were able to accurately perceive the potential differences in interaction difficulty between the two interface types.

Evaluation of Hypotheses

The results of this study provide strong support for the primary hypotheses proposed at the beginning of this research. The first hypothesis predicted that participants using the physical control interface would exhibit lower levels of distraction than those using the touchscreen interface, and the findings clearly support this hypothesis. Across nearly all objective metrics, the physical interface was associated with lower levels of visual distraction. Participants interacting with the physical control interface exhibited fewer glance deviations, fewer glances exceeding the two-second NHTSA threshold, and lower cumulative glance times across tasks. As a result, the physical interface condition produced substantially fewer overall NHTSA guideline violations compared to the touchscreen condition. These results indicate that physical controls allowed participants to complete in-vehicle tasks with less visual attention diverted away from the secondary visual attention task.

The second hypothesis predicted that participants using physical controls would report higher perceived safety, usability, and confidence than participants using the touchscreen interface, which was also largely supported by the subjective response data. Participants interacting with the touchscreen interface consistently reported higher perceived visual demand, lower usability, lower confidence in their ability to complete in-vehicle tasks while maintaining attention on the secondary visual task, and lower perceived safety when interacting with the interface while driving. In contrast, participants using the physical control interface generally reported feeling safer and perceived the interface as requiring less visual attention.

Role of Tactile Feedback in Interface Performance

An important factor that may explain the differences observed between the two interface conditions is the role of tactile feedback in driver-vehicle interaction. Physical controls provide haptic feedback that enables drivers to locate and operate controls through tactile discovery and muscle memory, allowing interactions to occur without the need for visual confirmation. When drivers eventually become familiar with the placement and feel of physical buttons, switches, or knobs, many tasks can be performed with minimal visual attention.

However, touchscreen interfaces largely lack these tactile cues. Because touchscreen controls do not provide distinct physical shapes or resistance that can be identified by touch, drivers must typically rely on visual search to locate interface elements before interacting with them. This visual confirmation requirement increases the likelihood that drivers will look away from the roadway (or a different visual task) in order to verify that the correct control has been selected. As a result, touchscreen interactions may lead to more frequent glance deviations, longer glance durations, and increased cognitive load.

These observations are consistent with the prior research and industry commentary discussed in the Background section. Critics of touchscreen-dominant vehicle interfaces have noted that the absence of tactile feedback requires drivers to visually monitor the interface during interaction, increasing eyes-off-road time (Sanchez, 2025; "Touchscreens Are Out, Buttons Are Back," 2025). Similarly, discussions of physical human-machine interfaces emphasize that tactile controls allow drivers to rely on muscle memory and physical affordances rather than continuous visual monitoring ("Why cars still need physical HMIs: the case for mechanical switching in modern vehicles," 2025).

Overall, this research reinforces the importance of tactile affordances in reducing visual demand during in-vehicle interactions, and suggests that the presence or absence of physical feedback may play a significant role in shaping driver distraction levels.

Noteworthy Findings

Several noteworthy findings emerged from the results, further contextualizing the relationship between interface design and driver interaction. One of these was the participants' strong preferences for hybrid or physical-heavy interface designs; no participant expressed a preference for a fully touchscreen-based interface. Rather, most participants indicated that they would prefer either entirely physical controls or a hybrid system combining physical controls with touchscreen functionality, suggesting that drivers value both the tactile accessibility of physical controls and the flexibility and broad functionality of digital interfaces.

At the same time, the results also indicate that physical controls are not without their own usability challenges. Although the physical interface generally produced lower distraction levels, some tasks still produced moments of hesitation or confusion for participants, highlighting that while interface modality plays an important role in interaction performance, control placement, labeling, and overall design quality are also critical factors in usability. Additionally, participant feedback suggested that certain types of tasks may even benefit from touchscreen interaction, indicating that touchscreen interfaces can offer advantages in situations where a visual grouping of related functions could assist in and simplify interaction.

These findings reinforce the idea that hybrid interface designs may provide the most balanced approach, allowing drivers to benefit from the tactile reliability of physical controls, while still providing the functionality and flexibility of touchscreen systems.

Discussion Summary

Overall, the results of this study indicate that touchscreen-based vehicle interfaces can significantly increase visual distraction compared to physical control interfaces. Participants interacting with the touchscreen interface exhibited more frequent and longer glance deviations, higher cumulative glance times, and slower task completion across most measured tasks, while the physical control interface generally enabled faster interactions and required less visual attention.

Participants' subjective perceptions closely aligned with these objective findings: touchscreen participants consistently reported higher visual demand, lower confidence, and lower perceived safety when interacting with the interface, while participants using the physical controls perceived the interface as safer and requiring less visual attention overall. Together, these results support the study's hypothesis that tactile controls can help reduce driver distraction during common in-vehicle interactions.

These findings highlight the importance of interface modality and control design in shaping driver interaction patterns, and provide a foundation for considering how vehicle interfaces can be designed to better support driver attention and safety.

Design Implications

Overview

The results of this study indicate that touchscreen-based vehicle interfaces can significantly increase driver distraction and task completion time when compared with traditional physical control interfaces. While touchscreen systems provide versatility and allow designers to consolidate many vehicle functions into a single display, this flexibility comes with important usability and safety tradeoffs. Across nearly all objective metrics measured in this study, participants interacting with touchscreen controls exhibited higher levels of distraction.

Physical controls, by contrast, consistently enabled faster task completion and required less visual attention from participants. Participants also reported feeling safer and more confident when interacting with physical controls. These findings suggest that tactile interaction remains an important component of effective in-vehicle interface design, and that physical controls should continue to play a central role in automotive dashboard systems rather than being completely replaced by touchscreen-only interfaces.

Control Hierarchy

The results suggest that not all physical controls are equally intuitive or easy to operate without visual attention. In the physical interface condition, participants occasionally struggled with less frequently used controls such as the defroster, indicating that drivers may rely heavily on familiarity and repeated use when developing the muscle memory needed to operate controls without looking away from the road.

These findings support the idea of a functional hierarchy of vehicle controls. Frequently used controls, such as volume, windshield wipers, and climate control, are more likely to become ingrained in muscle memory and can therefore be operated quickly through tactile feedback. Less frequently used controls may require occasional visual confirmation even when implemented as physical buttons or switches.

Extending this concept to modern infotainment systems suggests that vehicle interfaces should be organized according to both frequency of use and safety relevance. High-frequency or safety-critical controls should be assigned to the most accessible interaction mechanisms, such as steering wheel buttons or dedicated physical switches located near the driver’s hands, and less frequently used functions can be placed within touchscreen menus or secondary interface layers, where they remain accessible but do not compete with critical controls for dashboard space.

Designers should consider this hierarchy when determining the layout of vehicle dashboards. By carefully assigning functions to interaction methods based on their importance and frequency of use, designers can create systems that remain flexible while minimizing the visual demand placed on drivers.

Importance of Tactile Feedback

One of the clearest implications of this study is the value of tactile feedback in reducing visual distraction. Physical controls provide drivers with haptic cues that allow them to locate and operate controls without requiring constant visual verification. Once drivers become familiar with the location and shape of controls, they can rely on touch and muscle memory rather than visual search.

Touchscreen interfaces, by contrast, lack these tactile cues, and as a result, drivers must visually confirm the location of interface elements before interacting with them, and often must continue visually monitoring the interface to ensure the correct selection has been made. This reliance on visual confirmation increases glance duration and cumulative eyes-off-road time.

Designers developing touchscreen-based vehicle systems should consider ways to mitigate this limitation. Possible approaches include integrating haptic feedback, simplifying interface layouts, minimizing the number of interaction steps required to complete common tasks, and maintaining consistent spatial placement of frequently used controls across screens.

Hybrid Interface Approaches

Participant responses in this study also suggest that hybrid interface designs, which combine touchscreen displays and functionality with physical controls, may offer the most effective balance between flexibility and usability. No participant in the study expressed a preference for a fully touchscreen-based interface; rather, most participants indicated a preference for either entirely physical controls or a hybrid approach.

Hybrid designs allow designers to preserve the benefits of digital interfaces, such as customization, the ability to integrate updated software, and information complexity and quality, while still providing tactile controls for frequently used or safety-critical functions. This approach may help reduce driver distraction while still maintaining the versatility that modern infotainment systems offer.

Together, the findings of this study suggest that the most effective vehicle interfaces may not lie at either extreme of the design spectrum: instead, systems that strategically combine tactile controls with well-designed digital interfaces may provide the safest and most usable experience for drivers.

Limitations

Use of Parked Cars

Studying driver behavior in an automobile presents inherent challenges. Conducting research in real-world driving conditions introduces significant liability concerns, as driving itself is one of the most dangerous routine activities people undertake. For this reason, parked vehicles were used as the testing environment for this study; however, operating controls in a stationary vehicle is likely less cognitively demanding than interacting with those same controls while actively driving.

Similar studies have used driving simulators or closed-course track testing, though driving simulators offer limited applicability for this study protocol. In order to fully replicate the present setup, a simulator would require the integration of both a physical dashboard and a center touchscreen console, which would be incredibly complicated to source or develop. While such a system could potentially improve experimental control and expand future research possibilities, it was beyond the scope of this study.

Lack of Real Vehicle Motion

Because participants interacted with vehicle controls while the car was stationary, the level of external distraction was significantly lower than in a typical driving environment. To partially address this limitation and approximate the attention demands of real driving, the study protocol incorporated a secondary visual attention task in which participants were asked to read aloud numbers presented sequentially on a display positioned in front of them. However, this visual task remains an imperfect substitute for the dynamic visual environment of an actual road.

Driving simulators could address some aspects of this limitation, though not entirely, as many simulators rely on a single forward-facing screen, which does not accurately reproduce the full visual field of real driving; replicating realistic roadside distractions would require displays surrounding the driver. Additionally, the physical feedback provided by simulator controls often differs from that of controls in a real vehicle.

Closed-course track testing could introduce real vehicle motion, but such environments are typically far less complex than real-world traffic conditions. As a result, the increased cost and logistical difficulty of conducting the study on a closed course may not necessarily produce a proportionate improvement in ecological validity.

Interior Design Variation

Vehicle interiors vary widely across manufacturers and models; even if several vehicles employ similar control paradigms, the specific layout, labeling, and placement of controls can differ substantially between individual vehicles. As a result, findings derived from one vehicle may not generalize or apply to other vehicles, even those with similar interface types. Even within the same brand or model line, design changes between generations can significantly alter control layouts, meaning that drivers familiar with one version of a vehicle may find a newer model difficult to navigate. This variability also complicates the process of selecting an appropriate participant pool.

Participant Familiarity

An early version of the study protocol placed participants in preselected vehicles in order to control for differences in interior design; however, this approach introduced a significant unfamiliarity bias. Participants were often confused by interfaces they had never encountered before, leading to unusually high distraction levels that reflected their unfamiliarity, rather than issues with the interface modality or design. In order to eliminate familiarity levels as a potential confounding variable, the study protocol was modified so that all participants could perform the study tasks in their own vehicles. While this change helped control for differences in participant familiarity with the vehicle interfaces, it also introduced additional logistical constraints.

Small Sample Size

Requiring participants to complete the study tasks in their own vehicles significantly reduced the available participant pool. The study required that all vehicles used in the experiment support the same set of control functions being tested, and maintaining this consistency across both the physical control and touchscreen interface conditions further constrained participant selection. As a result, participant recruitment was largely determined by the types of vehicles that potential participants owned.

Human Variability Between Participants

Participants approached some tasks differently, even when given identical instructions. In some cases, participants attempted to use alternative controls or completed tasks in ways that differed from those anticipated in the protocol, which introduced additional variability in task completion time that was not directly related to the interface type being studied. Increasing the sample size would help mitigate this effect.

Study Revisions and Time Constraints

Early iterations of the study protocol revealed practical challenges that required refinement and revision. While these adjustments improved the overall study design, they also reduced the amount of time available for participant recruitment and data collection.

Exclusion of Steering Wheel Controls

The study design compared the performance of tasks completed using touchscreen controls versus those completed using physical controls. However, steering wheel-mounted controls were not included as a separate interface category. In the touchscreen vehicles used for the study, some functions were also available through steering wheel controls, though participants were instructed not to use these controls during the experiment in order to isolate the effects of touchscreen interaction.

Despite this, during the study, several participants instinctively reached for the steering wheel controls before remembering that they were instructed not to use them. This behavior suggests that participants were accustomed to performing certain tasks, such as adjusting volume, using the steering wheel controls rather than the touchscreen. This may have resulted in participants spending additional time completing tasks, as they would need to recall how to perform those same functions through the touchscreen.

Manual Data Coding

Data logging for this study was performed manually, with researchers reviewing multi-angle videos of each session and recording participants' actions and glance behavior. This approach introduces the potential for human error and limits the accuracy of the recorded data. Automated data collection methods, such as eye-tracking systems or other movement-tracking tools, could provide more consistent and reliable measurements in future studies.

Timestamp Precision

Because session data was recorded by reviewing video footage, the accuracy of timing measurements depended on the capabilities of the video playback software. The software used during analysis did not display timestamps with millisecond precision, which introduced minor rounding errors into the recorded timing data.

Future Work

This study suggests that a potentially significant difference in task completion time may exist between touchscreen-based and physical control vehicle interfaces. However, due to the limitations described above, the findings have limited generalizability. Future research in this area could improve upon the present study through several methodological enhancements.

Larger Sample Size

Increasing the sample size would help reduce variability in the data and improve the reliability of the results. A larger participant pool would also make it easier to account for individual differences in driving habits, familiarity with vehicle controls, and interaction strategies. Allocating additional time for participant recruitment would help ensure that an adequate number of participants meeting the study criteria can be identified.

Real Driving Environment

Although the visual attention task introduced an element of forward attentional demand, performing the study procedures in a stationary vehicle differs significantly from performing the same tasks while driving. Future studies could address this limitation by incorporating driving simulators or controlled closed-course driving environments, as these approaches would allow researchers to introduce motion and environmental complexity while still maintaining a safe testing environment.

Eye-Tracking Software

The use of eye-tracking software could improve measurement accuracy by reducing the potential for human error when calculating eyes-off-road or “eyes-off-task” time, and would also allow for more precise measurements of glance duration and gaze patterns. Such systems could be used during the experimental session itself or applied to recorded footage during post-processing.

Effects of Interface Familiarity

A key limitation of the current study was the requirement that participants perform the tasks in vehicles with which they were already familiar. While this approach helped control for familiarity as a confounding variable, it also limited the ability to study how interaction performance changes as users learn a new interface. Future research could investigate how driver performance evolves when users are initially unfamiliar with an interface and gradually develop familiarity over time. Determining the amount of exposure required for drivers to reach a basic level of proficiency would provide additional insight into how interface design influences usability.

More Hybrid Designs

In practice, most modern vehicles do not exclusively provide entirely touchscreen or entirely physical controls; rather, they usually incorporate hybrid systems that combine elements of both modalities. However, the specific balance between touchscreen and physical controls can vary between vehicles, and some of these modality variations may lead to increased distraction and decreased perceived usability. Rather than conducting a binary comparison between physical and touchscreen vehicle controls, future studies could examine a wider range of interface designs.

Conclusion

This study examined the relationship between vehicle interface design and driver distraction by comparing touchscreen-based controls with traditional physical controls. Through a combination of objective performance metrics and subjective participant feedback, the results revealed clear differences between the two interface types. Across nearly all measured metrics, the touchscreen interface required greater visual attention, produced more frequent and longer glance deviations, and resulted in substantially higher cumulative “eyes-off-task” time compared to the physical control interface. These differences were also reflected in task performance outcomes, with touchscreen participants generally taking longer to complete tasks and experiencing more hesitation or correction during interaction.

Participants’ subjective perceptions closely aligned with these objective findings. Participants using the touchscreen interface reported higher perceived visual demand, lower confidence when completing tasks while maintaining attention on the visual task, and lower perceived safety overall. In contrast, participants interacting with physical controls generally reported feeling more comfortable and required less visual attention to complete the same tasks. Together, these results support the study’s central hypothesis that tactile interaction through physical controls can reduce driver distraction during common in-vehicle tasks.

At the same time, the results also suggest that interface modality alone does not fully determine usability. Even within the physical interface condition, certain tasks produced moments of hesitation or confusion, indicating that control placement, labeling, and overall interface design remain important factors in minimizing distraction. Participant responses also highlighted a broader preference for hybrid interface systems that combine the tactile reliability of physical controls with the visual flexibility of digital displays.

Overall, these findings contribute to ongoing discussions about the safety and usability of touchscreen-dominant vehicle interiors. As automotive manufacturers continue to integrate increasingly complex infotainment systems into vehicle dashboards, understanding how interface design affects driver attention will remain an important area of study. Building on the results of this research, future work will explore how touchscreen interfaces might be redesigned to reduce visual demand and better support driver attention, with the goal of developing interface concepts that incorporate the advantages of both tactile and digital interaction.

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