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Evaluating the dissociation between drivers' self-perceived and objective need for vehicle assistance during obstacle avoidance tasks

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Abstract
Driver-assistance systems are becoming more commonplace; however, the realized safety benefits of these technologies depend on whether a person accepts and adopts automated driving aids. One challenge to adoption could be a preference-performance dissociation (PPD), which is a mismatch between a *self-perceived* desire and an *objective* need for assistance. Research has reported PPD in driving but has not extensively leveraged driving performance data to confirm its existence. Thus, the goal of this study was to compare drivers' self-reported need for vehicle assistance to their objective driving performance. Twenty-one participants drove on a simulated road and traversed challenging, real-world roadway obstacles. Afterwards, they were asked about their preference for automated vehicle assistance (e.g., steering and braking) during their drive. Overall, some participants exhibited PPD that included both over- and underestimating their need for a particular type of automated assistance. Findings can be used to develop shared control and adaptive automation strategies tailored to particular users and contexts across various safety-critical environments.

Keywords
decision making, driver behavior, driving simulation, preference performance dissociation

Introduction

Technologies with increasing levels of intelligence are infiltrating every area of our lives. In safety-critical environments, such as driving, systems are being built that can better handle dynamic and, often, unpredictable situations. However, it is not always clear how the human should intervene in a given task when interacting with these systems. The Associated Press reported a synthesis of two studies that found that when systems such as automatic emergency braking and forward collision alerts are properly enabled in the vehicle, an overall 49% decrease in front-rear crashes and a 53% decrease in rear crashes could be achieved (Krisher, 2022). The realization of this potential safety benefit depends on whether and how much a person voluntarily uses these automated driving aids. However, often, people are not always accurate at estimating their need for assistance in completing a particular task with respect to their ability to do so without any support. This mismatch can result in a phenomenon known as "preference-performance dissociation" (PPD), where there is a disconnect from our self-perceived needs and our empirical needs (Andre & Wickens, 1995).

One factor that can contribute to PPD is the salience of a given task, or the amount of time that has lapsed between the end of the task and the evaluation of a person's preference and/or performance. PPD has even been found to occur when a person evaluates their own performance immediately after completing a task (high salience) (Andre & Wickens, 1995). Also, the "mere-exposure effect," i.e., length of time a person is exposed to the given task, has been reported to be directly and negatively correlated with PPD (Roberts et al., 2017). Thus, Andre & Wickens (1995) caution that "user performance should *always* augment preference ratings (p. 4)" and that this knowledge should be used to design a system that supports the best performance and not just what is preferred by the user.

In driving, van Driel & van Arem (2005) investigated, via international questionnaires, user needs for driving assistance by asking questions related to: "driving support function," which focused on drivers' preferences for assistance relating to vehicle warnings as well as "driver support

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system," which focused on the situation(s) for which the vehicle provides assistance. They found that the greatest need with respect to driver support functions was for the vehicle to provide a warning to drivers about traffic conditions, specifically on a motorway, which is a high-speed driving environment (van Driel & van Arem, 2005). For the driver support system, they also found that most respondents wanted vehicle assistance in situations with reduced visibility and for imminent crash situations. The authors note, however, that one of their limitations, and a need for future research, is to "[verify through] a driving simulator experiment in which their driving [behavior] and workload as well as their acceptance will be studied (p.17)." This means that in addition to the qualitative assessment, an experiment should be conducted to compare objective driving performance to subjective responses.

More recently, in a different study, Kaß et al. (2019) examined driver's subjective hazard perception in comparison to driver's self-reported need for driving assistance. Though the experiment employed a driving simulator, the researchers timed the driving simulator to terminate at a predetermined time-to-collision, such that no objective driver performance data was collected. They found drivers' perceived need for assistance to be positively correlated with the drivers' subjective hazard perception. In other words, participants perceived the need for vehicle assistance when the situation appeared to be more safety-critical (Kaß et al., 2019). Similar to the other studies' limitations, the authors acknowledge that while they purposely examined self-reports for perceived needs and did not record measures for needed assistance, there is a critical research need to compare self-reported to objective needs for assistance (Kaß et al., 2019). This is even more crucial given the growing number of automated driving systems (ADS) available for personal use on public roadways.

The goal of the present study is to contribute to this body of work by comparing drivers' self-perceived need for vehicle assistance, reported after the completion of a driving task, to their objective driving performance to determine whether the preference-performance dissociation phenomenon exists. In contrast to previous studies that only evaluated subjective, self-reported data of user needs, in this paper, we present preliminary findings from a larger experiment that sought to capture and understand naturalistic driving behavior using advanced driving simulations. In summary, participants were asked to complete an approximate 30-minute drive on a rural road with various road obstacles along their route. Afterwards, they were asked a series of questions related to their driving strategies and their perception of vehicle assistance. Then, their objective driving performance was compared to their self-perceived need for vehicle assistance. Ultimately, findings from this work can be used to inform the development of shared control strategies as well as adaptive automation (Inagaki, 2003) that is sensitive to user and context in driving and other safety-critical environments.

Method

Participants

Twenty-one participants (11 males, 9 females, 1 non-binary), with a mean age of 25 years (range: 18 to 61), volunteered for this study. Participants were from a convenience sample compromised of students and a non-student. The average number of years driven within the U.S. was 7.14 years (range: 1.5 to 42), and the average of years driven outside of the U.S., including the U.S. driving experience, was 8.10 years (range: 1.5 to 46). Also, nine out of the 21 participants reported driving less than 10k miles/year, eight drove an average of 12k miles/year, and four reported driving more than 15k miles/year (all pre-COVID-19 travel estimations). This study was approved by Purdue University's Institutional Review Board (IRB-2020-755).

Equipment

This study used a fixed-base medium-fidelity driving simulator developed by the Driving Safety Research Institute (DSRI), miniSim^{TM}. The system is equipped with three 48-inch monitors and one 18.5-inch monitor for displaying the driving environment and the vehicle dashboard display, respectively. There are also two foot-pedals and a steering wheel to capture driver inputs. The miniSim^{TM} system's sampling rate is 60Hz.

Driving Scenario and Independent Variable

The driving scenario was a two-lane rural road environment. The roadway topography consisted of flat segments, multiple curves, and hills. Obstacles (the independent variable with 4 levels) were placed throughout the drive and occurred approximately 5-8 minutes apart from one-another (see Figure 1 for a sample road network). The obstacles were intentionally selected to represent increasing levels of difficulty, in terms of how drivers might avoid the obstacle (see Table 1), as identified as "unexpected/relevant objects derived from normal driving scenarios" in (Thorn et al., 2018)'s NHTSA report.

A Latin Square Design (4 x 4) was utilized to counterbalance ordering effects across participants. Oncoming vehicles, in the left adjacent lane, were randomly presented throughout the drive, but not when the subject vehicle was approaching any obstacle events. Also, obstacles were concealed in the environment until participants approached them. To help make the obstacle less visible, stalled vehicles were present along the shoulder of the road during the drive, two of which were decoys, and the other was an 18-wheeler tractor trailer (which masked the deer obstacle #4). This was done to ensure that participants did not see the upcoming obstacle (deer), before it suddenly walked into the middle of the road. There was only one leading vehicle during the

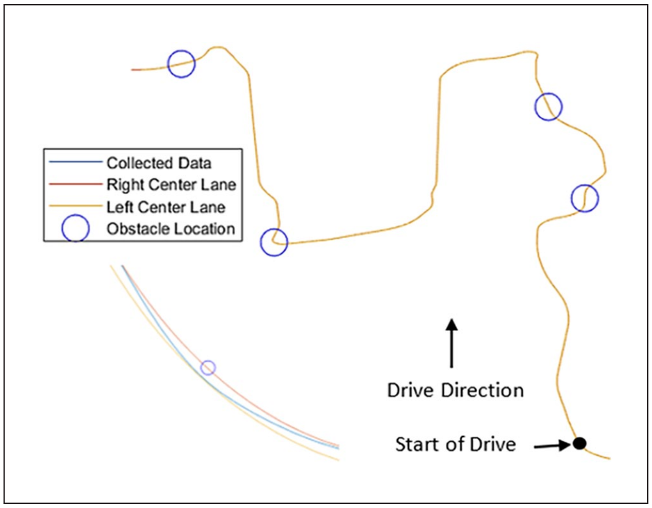

Figure 1. Bird's-eye view of sample road network of driving scenario with right and left reference lanes and driver (collected) data; zoomed in reference window (left-side image) (similar to Luster & Pitts, 2022).

drive, which related to the construction zone obstacle (#3; more details in Procedure section below).

Procedure

Participants were first asked to sign a consent form. Afterwards, they were asked to complete a practice drive (different from the actual drive) on an open highway to familiarize themselves with the driving simulator. The actual driving scenario was comprised of the four obstacles that unexpectedly appeared along the drive, triggering the need for an avoidance task/maneuver. Participants were instructed to drive along the rural road (see Figure 2) and avoid any obstacles in the roadway that might be present. Specifically, each participant was given the same set of instructions: (1) drive as you normally would on the road, (2) drive at 60 mph, or any other posted speed sign, and if anything in the environment makes you cautious, do what you think is best, for example, (3) you can steer or go around an obstacle to ensure that you maintain control of your vehicle at all times, (4) however, do not come to a complete stop and do not pass any traffic/leading vehicles. The only leading vehicle in the driving scenario was a cement truck that merged into traffic and led the participant to the construction zone obstacle. This truck was designed to keep the construction zone hidden until participants reached the zone and, at that time, the cement truck exited to the shoulder and the obstacle (signs, barricades, and construction workers) was revealed.

Each participant drove the scenario only once and was not made aware of the (different types of) obstacles nor when they would occur. Participants were also not guided on how they should avoid any obstacle. The drive lasted approximately 30 minutes, with three intermediate breaks.

Dependent Measures and Data Analysis

For this subset of data, (driving performance) dependent measures included: maximum braking force (MBF), maximum steering wheel angle rate (SWAR), continuous speed on approach, and responses to debriefing interview questions.

Driving performance measures. The maximum brake force (in lbf) represents the amount of force exerted by the participant and applied to the brake pedal during obstacle avoidance. It was recorded during a 5-second time window before the location of the obstacle (at time zero) to capture driving behavior when approaching the obstacle. The maximum steering wheel angle rate (degree/second) is the displacement of the steering wheel (in degrees) over time (in seconds). This was observed over the same time window as the MBF. Continuous speed on approach is the speed at which the driver was traveling prior to encountering the obstacle. This time window was set to 5 seconds prior to the deer obstacle and was also considered in the overall driving behavior observation (See Figure 3).

Participants completed a single drive that included four different obstacle types. As mentioned, the deer obstacle was ranked by the researchers as the most difficult, referring to Czarnecki (2018), who reviewed roadway driving behavior based on the size of domestic animals and wildlife that may encounter vehicles; he found that the most severe animal-vehicle crashes involved larger wild animals, such as a deer. In addition, due to paper space constraints, we only report the driving behavior analysis related to the deer obstacle. The moving deer was hidden behind the stalled 18-wheeler on the shoulder of the road, which prompted participants to develop a unique strategy to avoid it. Steering wheel angle rate, though a continuous variable, was taken as a moment in time where the participant experienced their maximum SWAR within their approach to the deer.

Subjective data. A qualitative debriefing interview was conducted with each participant immediately after the experiment. The debriefing interview included six questions recounting participants' overall driving strategies used, experimental expectations, and their perspective on the usefulness of and preference for automated vehicle assistance during off-nominal events. The main question of focus was: "What assistance, if any, would you want the vehicle to give during adverse events similar to the ones you encountered during the drive?" Preferences for assistance were categorized by type: (1) steering only, (2) braking only, (3) steering and braking, (4) a combination of either (1-3) with alert and/or heads-up display, (5) full assistance (consisting of steering and braking and alerts via auditory and heads-up display – meaning that they would transition from fully manual to fully autonomous mode in that given instance), and (6) no assistance at all (no vehicle control with or without alerts).

Table 1. Independent variable (obstacle type: 4 levels) ordered in terms of difficulty (similar to Luster & Pitts, 2022).

Level of Difficulty	Description	Obstacle Type
1	*Tire* – old tire in subject's center driving lane to mimic road debris	Small static object (obj.)
2	*Construction Zone* – road signs, barriers, workers, and cement truck	Large static obj.
3	*Rain & High Winds* – brief (~ 5 sec) heavy rain and high velocity wind gusts onset	Small dynamic event
4	*Deer* – emerged into road, crossed driver's lane, and stopped	Large dynamic obj.

Figure 2. Sample participant driving on rural road.

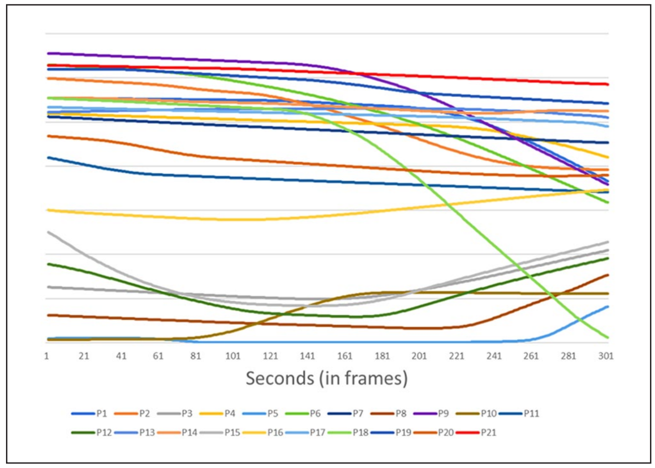

Figure 3. Continuous speed on approach to deer obstacle (60Hz frames with location of obstacle at frame 300) (best if viewed in color).

Data Analysis. Inferential statistical analysis is not applicable given our research question and the nature of the data collected. Therefore, we analyzed the data using ratios, percentages, and overall visual/graphical trends.

Results

Driving Performance

Continuous speed was captured 5 seconds on approach to the obstacle to understand vehicle handling both as a group and individually. Figure 3 displays the speed trajectory of each participant as they approached the deer obstacle. Overall, participants approached the deer by (1) maintaining a consistent speed (~48% of participants), (2) decelerating (~25%), or (3) initially coming to a complete/near stop and then subsequently accelerating toward the deer (~27%). Of those, participant 18 (lightest green line) was the only one to collide with the deer. Maximum braking force (Figure 4) and maximum SWAR (Figure 5) findings are discussed in the context of preference-performance dissociation in the following sections.

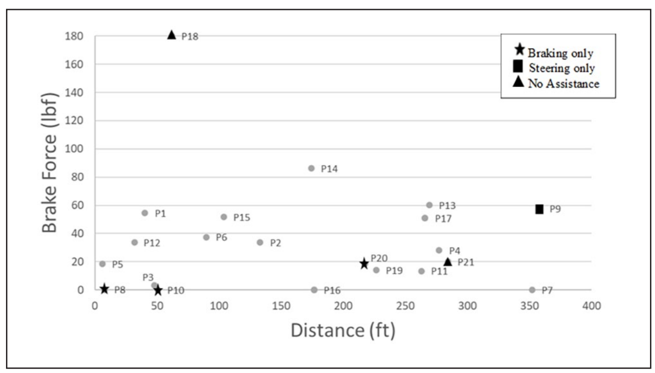

Figure 4. Scatterplot capturing MBF for each participant on approach to deer obstacle (5 secs until location of deer at 0 ft).

Qualitative Debriefing Analysis

All participant responses were transcribed using an AI transcription service (Otter.ai) and verified by a researcher. The transcribed responses for the question: "What assistance, if any, would you want the vehicle to give during adverse events similar to the ones you encountered during the drive?" were then placed into category types (see Table 2 below for additional detail). Of the responses, participants most preferred (~ 43% of participants) to have full steering control and for the vehicle to only control emergency braking. The second most reported preference was for both steering and braking assistance (~26% of participants), i.e., as they would have no manual control over the vehicle at that moment. Three out of 21 participants wanted steering only, while remaining in control of braking. Two participants wanted no

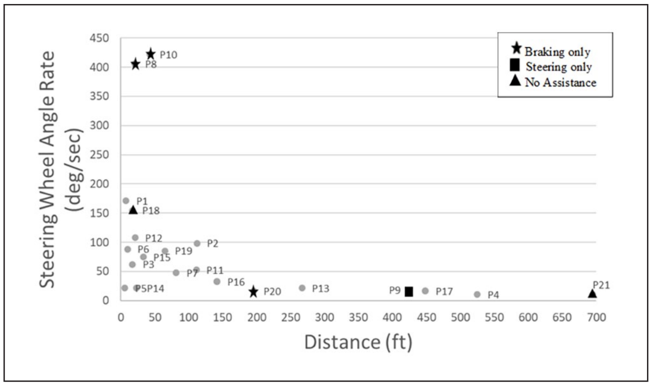

Figure 5. Scatterplot capturing maximum SWAR for each participant on approach to deer obstacle (5 secs until location of deer at 0 ft).

vehicle control assistance at all, and another two participants who wanted full vehicle control (steering, braking, and vehicle warnings).

Preference-Performance Dissociations

Comparing participants' self-perceived need for different types of driving assistance against their individual objective driving performance during the deer encounter, there were some participants whose (1) preferences contradict their performance (presence of a dissociation) or (2) performance is aligned with their preferences. In the first case, participants 8 and 10 both explained that they would want the vehicle to provide partial assistance via automatic braking only and would not want steering assistance while encountering an obstacle. However, with respect to their SWAR performance, both participants displayed very high maximum steering wheel angle rates compared to other participants, even though not at high speeds. Participant 20 also wanted braking assistance only. However, compared to the other drivers' reaction to this encounter, their braking and steering performance suggests that their performance is adequate even without braking assistance. Participant 9, on the other hand, self-reported a preference for steering assistance only, however, given their overall speed, braking, and steering performance, they appeared to have navigated the obstacle very well without assistance. Last, there were two participants who self-reported their preference to be no vehicle assistance of any kind, that is, participants 18 and 21. Participant 18 had a high MBF, a high maximum SWAR when very close (~50ft) from the deer, and ulimately collided with the deer. This suggests that this participant may be experiencing a dissociation between their perceived preferences for vehicle control and their ability to be able to handle the task with sufficient performance. Participant 21, on the contrary, stated preference is more aligned with their own performance such that their vehicle handling at a distance greater than 250ft from the deer allowed them to make a minimal risk manuever.

Discussion

The goal of this study was to perform a preliminary comparison of drivers' self-perceived need/preference for automated vehicle assistance with their objective obstacle avoidance performance. Overall, there was evidence of a preference-performance dissociation (PPD) effect such that handling performance of some drivers, who explained not needing a particular type of assistance, was poor.

Particularly, we found that there were (1) participants who exhibited PPD characteristics such that their handling of the vehicle was poorer than the assistance they perceived themselves to need, (2) participants whose self-perception was aligned with their preferences for desired vehicle control, e.g., they stated they did not need a type of assistance and their driving data suggests that they actually did not, and (3) individuals who stated that they would prefer the vehicle to give a certain type of assistance, while their performance suggests they would not need that particular type of assistance.

It is likely that, for cases #1 and #3, participants mis calibrated their own obstacle avoidance skills, which has been documented in the driving literature. The theory of self-perceived driving abilities (SPDA), i.e., the subjective opinion that a person has regarding his/her own driving abilities, can help to explain why drivers may over- or underestimate their driving abilities (Huang et al., 2020). This phenomenon is a universal problem and has been observed in drivers of all ages (Huang et al., 2020). Particularly, for younger drivers, who are the primary participants in this study, researchers posit that this effect may be the result of not having many years of driving experience to perform accurate assessments of their skills (e.g., De Craen et al., 2011; Matthews & Moran, 1986). It is also possible that other demographic factors, such as one's risk propensity, could contribute to a miscalibration between perceived and actual driving abilities. In any case, a variety of approaches currently exist to help drivers calibrate their perception of their own driving skills, such as educational interventions (e.g., Nasvadi, 2007) and driver training programs (e.g., Selander et al., 2019). But, given significant advancements in artificial intelligence and machine learning, there is also an unprecedented opportunity to design shared control algorithms (Johns et al., 2016) and adaptive automation schemes that can be tailored to individual driving behaviors in order to help calibrate drivers' perception of needed support and combat risky driving.

Analysis of the collected data is currently ongoing. However, a few limitations of the current study should be noted. First, we did not present findings related to the other obstacle types (i.e., tire, construction zone, and wind and rain), which will be included in a follow-up publication with inferential statistics. Second, this study has not yet selected a

Table 2. Post-experiment self-perceived vehicle assistance needs: Individual designation by category.

		PARTIAL ASSISTANCE				
PARTICIPANT	NO ASSISTANCE	STEERING	HEADS-UP DISPLAY	ALERT	BRAKING	FULL ASSISTANCE
1		✓			✓	
2		✓				
3						✓
4				✓	✓	
5		✓			✓	
6					✓	
7			✓		✓	
8					✓	
9		✓				
10					✓	
11		✓			✓	
12			✓		✓	
13			✓		✓	
14		✓		✓		
15		✓			✓	
16		✓			✓	
17			✓		✓	
18	✓					
19						✓
20					✓	
21	✓			✓		

standard measure of driving performance that combines speed, steering, and braking metrics to classify behavioral patterns as unsafe. Here, we rely on comparisons to other drivers, but more objective measures based on standards defined by governing agencies, such as the National Highway Traffic Safety Administration (NHTSA) and Society of Automotive Engineers (SAE), will be adopted. This study also represents a single point interaction with the driving task, but a longitudinal approach would enable better delineation of how perceptions of the need for automated assistance change over time as drivers receive additional feedback regarding their obstacle avoidance abilities. Finally, our participant sample included mostly younger adults, but PPD is not exclusive to younger drivers and should be investigated across a wider age group.

Conclusion

In summary, preference-performance dissociation (PPD) is a phenomenon that can negatively affect performance in many safety-critical environments, especially driving. Our study provides preliminary evidence that PPD exists between drivers' perception of their need for automated vehicle assistance and their ability to navigate challenging roadway obstacles. This work represents only one area of activity within a larger NSF-funded (Grant #1836952; Program Manager: Dr. Sylvia Spengler) Cyber-Physical Systems (CPS) project that seeks to understand human behavior, performance, and physiological responses in applied environments and build control algorithms that are responsive to human behavior across various complex domains.

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