EXPLORING DRIVER DISTRACTION IN ADAPTATION TO LOWER LEVELS OF AUTOMATION: OLDER ADULT DRIVER COMPARISONS

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ABSTRACT

This project examined how middle-aged and older drivers adapt to the use of Level 2 (L2) advanced driver assistance system (ADAS) features (i.e., the system controls lateral and longitudinal motion). Data were drawn from two naturalistic driving studies (NDS). In the *L2 NDS* study, 82 participants were recruited from the Washington, DC metro area and drove L2 vehicles for four weeks. A second NDS was conducted with 14 older adults (*Older Driver NDS*). In the Older Driver NDS, participants aged 70-79 drove L2 vehicles for six weeks. Speed setting above the speed limit was significantly more common when L2 was active than when it was available-but-inactive in the *Older Driver NDS* dataset. Older adults had shorter off-road glances than middle-aged drivers in the *L2 NDS* when L2 was available, regardless of L2 engagement status. Older drivers showed shorter glance durations overall. Older adult drivers had fewer glances away from the forward roadway and were significantly less likely to engage in secondary tasks when L2 was active. Evidence of older adult driver adaptation to L2 systems is seen most predominantly in the speed selection.

INTRODUCTION

Driving automation technology is rapidly proliferating into the U.S. vehicle fleet. Along with this trend, our society is aging. In light of this, questions remain regarding how older adult drivers adapt to novel technologies in the driving environment and how drivers respond to the introduction of new technology that serves specific needs. The primary research objective was to compare middle-aged and older adult driver safety behaviors and adaptation during initial exposure to SAE International (SAE) Level 2 driving automation (L2) advanced driver assistance systems (ADAS).

Vehicle automation control paradigms are becoming more novel across a variety of dimensions, specifically L2, where some degree of driving automation control is simultaneously exerted in the longitudinal as well as lateral dimensions. Typically, longitudinal control is manifested by adaptive cruise control (ACC) and lateral control via lane keep assistance (LKA) or lane centering assistance (LCA). Additionally, we are witnessing an aging of our society.. While there are theoretical approaches to conceptualizing driver adaptation (e.g., *risk homeostasis*, [1,2]; *risk allostasis*, [3]), questions remain about how older adult drivers specifically adapt to automation in the driving environment. The construct of adaptation is perhaps even more complex with older drivers in that cognitive decline may progress with age.

A few studies have examined this space. In a study focused on situation awareness in a simulated driving environment, researchers found that a group of older drivers (65–81) adapted to dynamic hazards with greater vehicle speed reduction than a group of younger drivers (18–25) [5]. While each study is unique, the naturalistic driving study (NDS) research paradigm typically involves the automatic recording of driver behaviors, vehicle kinematics (including speed and acceleration), and a GPS record of the vehicle's route driven. Liang and colleagues used the NDS paradigm to investigate older drivers' subjective adaptation to ADAS, including ACC over a 6-week period [6]. Weekly phone surveys found little change in the older drivers' trust of the ADAS features: they generally started high and remained at that level. However, focus group discussions conducted after the conclusion of the driving portion of the study did reveal attitudinal adaptation to the technologies across several dimensions, including perceived safety and functional benefits as well as confidence in the technology.

Objective

The objective of these analyses is to compare middle-aged and older adult driver safety behaviors during initial exposure to L2-equipped driving automation (i.e., driving automation to simultaneously control lateral and longitudinal motion, but where driver expected to maintain constant supervision of these support features and maintain responsibility for driving). This analysis provides a comparison that identifies how older drivers adapt to driving automation to discuss potential unique needs of that population.

METHOD

Two NDS databases were used to compare older adult drivers with a group of middle-aged drivers in the earliest phases of L2 technology use. The *Older Driver NDS* was conducted with 18 older drivers (70–79) [7]. Participants drove one of four L2-equipped vehicles for 6 weeks each. Vehicle makes included Audi, Infiniti, Mercedes, and Volvo from the 2015 – 2017 model years. Participants were eligible for the study if they met the age group criterion and had not driven L2-equipped vehicles. The *L2 NDS* study provided a database of middle-aged drivers, 25-54, for comparison with the older adults in the Older Driver NDS [8]. The same vehicles as were driven in the Older Driver NDS were also driven in the L2 NDS; however, the L2 NDS also included a Tesla. L2 NDS participants lived and commuted in the Washington, D.C. area. Participants in the Older Driver NDS were residents of the Blacksburg, Virginia, and surrounding areas. Data from both datasets were compared over the first 3 hours of driving exposure *with use of the L2 technologies*. While drivers in the L2 NDS database had more exposure to L2 technologies, older drivers did not use systems more than 3 hours, so older driver usage limited the amount of L2 exposure that could be used in this analysis.

Data were analyzed from 96 volunteer driver participants. This included 14 drivers from the Older Driver NDS and 82 drivers from the L2 NDS. There were 2,437 L2 activations, which included 130 activations from the Older Driver NDS and 2,307 activations from the L2 NDS. These observations were collected across 3,891 trips, including 370 trips from the Older Driver NDS and 3,521 trips from the L2 NDS. Table 1 provides a summary of these observations.

Table 1. Summary of Older Driver NDS and L2 NDS Data Sources

Data	Older Driver NDS (70+ years old)	L2 NDS (25 to 54 years old)
Drivers	14	82
L2 activations	130	2,307
Trips	370	3,521

The primary independent variable focused on L2 Activation Status, where the driver (i.e., systems were available but inactive) or the driving automation (i.e., the systems were both available and active) controlled both lateral and longitudinal motions of the vehicle. Additional independent variables include Time of Day, Day, Road Type, and Traffic Density. The main dependent measures included: speed selection, glance behaviors, and secondary task engagement. While this study intended to examine changes in driver behavior over time, older drivers did not use the systems enough (i.e., no more than 3 hours of experience with active L2 systems) to conduct this analysis.

RESULTS

Across both datasets, the duration of each individual L2 activation event was similar. In the Older Driver NDS, 90 percent of activations were shorter than ten minutes; in the L2 NDS, 99 percent of activations were shorter than ten minutes. This analysis evaluated multiple circumstances that included time of day, weekday versus weekend, and road type, but these factors were not found to influence any of the variables in this analysis.

Speed Selection

For each L2 system activation, vehicle speed, GPS coordinates, and road type were recorded. Each L2 system feature activation analyzed was required to be at least 120 seconds in duration to ensure the driver intentionally activated the L2 system features. Then, a random sample of matched controls was identified with the goal of a 1:1 match based upon driver identification number, Time of Day (± 4 hours), day of week (weekday versus weekend), and anytime the vehicle was traveling above 40 mph. The idea of *available-but-inactive* is important in ensuring comparisons are reasonable. That is, if comparisons were made between L2 usage periods and *all* non-L2 usage periods, any observed differences could readily be attributed to the different conditions, scenarios, and driving environments in which drivers tend to - or are permitted to - engage L2 systems. Using available-but-inactive driving epochs to provide control samples makes usage/non-usage comparisons more meaningful.

The speed profiles are shown in

Figure **1** as a histogram of the difference between speed limit and actual speed. Frequencies in each bin are plotted as a percentage of total events. Note that in these figures, the middle of the x-axis (zero) is representative of adhering to the speed limit (and is marked with blue vertical lines). Histogram bars to the right of zero indicate traveling faster than the speed limit, and bars to the left indicate traveling slower. Both L2 status, $F(1, 18{,}010) = 1{,}157.35$, $p < 0.001$, and driver groups, $F(1, 78) = 14.26$, $p < 0.001$, demonstrated statistical significance in speeding behaviors. When L2 systems were active, drivers tended to select speeds which were 4.4 mph faster than the average speed driven when the L2 system was available-but-inactive. In addition, middle-aged L2 NDS participants tended to drive 5.2 mph on average faster than the Older Driver NDS participants. In addition, the frequency with which older adults selected speeds over the speed limit was significantly more common when L2 was active than available-but-inactive ($F(1, 1{,}230) = 425.71$, $p < 0.001$).

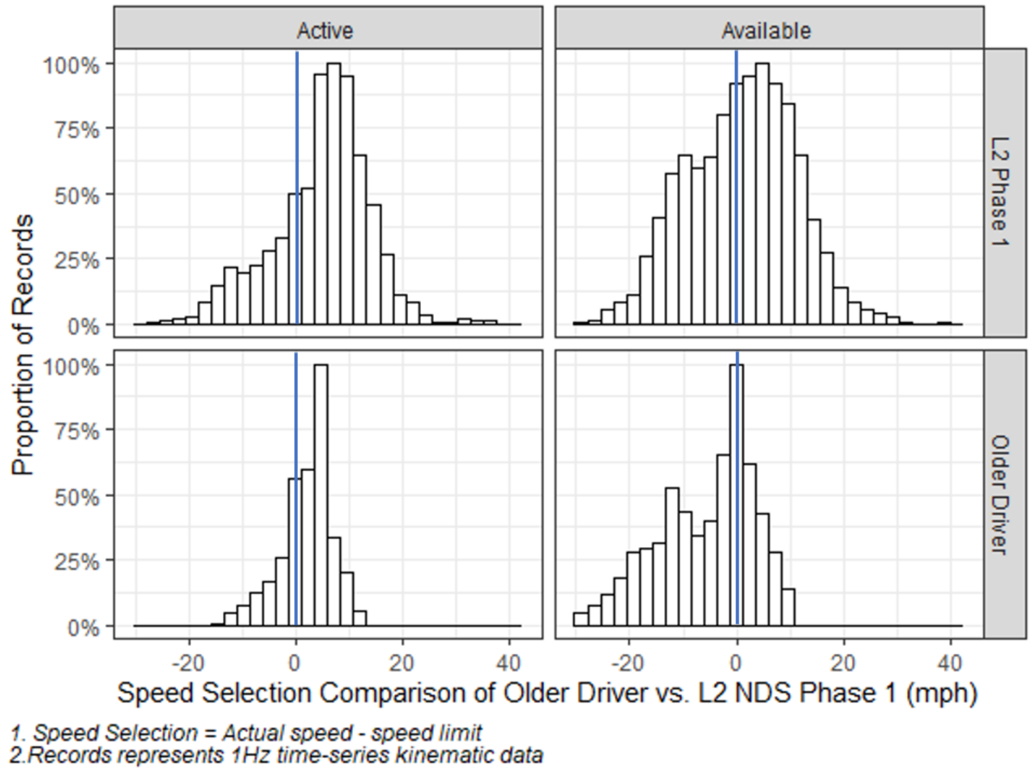

Figure 1. Histograms of speed selection profiles relation to speed limit comparison by L2 status and participant group (Older Driver vs. L2 NDS Phase 1) – speed limit represented by blue vertical lines.

Glance Behavior

Eyes-off-road variables for all eye glances away from the forward roadway are shown in

Figure 2. This figure displays four graphs of eye-glance data across both datasets for samples with L2 active and samples with L2 available-but-inactive for both the Older Driver NDS and the L2 NDS. There were several samples where eye-glances away from the forward roadway did not occur. This resulted in several values of zero in the dataset. The zeros were removed before analyzing these data to provide a clearer analysis of what eye-glance behavior looks like when it does occur. ANOVA tests were used to analyze all four metrics of eye-glance data.

Total off-road glance duration is plotted in the top left panel (**A**). Results showed that participants in the Older Driver NDS had shorter total off-road glance duration (i.e., per driver) than L2 NDS participants, both when L2 was active and when L2 was available but inactive. This was evidenced by a main effect of driver group, $F(1, 609) = 6.58$, $p = .01$. There was no significant main effect of whether L2 features were active versus available-but-inactive on total glance duration ($F(1, 609) = 3.02$, $p = 0.083$). Mean off-road glance duration is plotted in the top right panel (**B**), and showed main effects of both L2 active, $F(1, 609) = 9.00$, $p = .003$, and driver age group, $F(1, 609) = 7.36$, $p = .007$. Overall, L2 NDS drivers had longer mean glance durations compared to those in the Older Driver NDS. Single longest off-road glance (bottom-left panel, **C**) showed main effects of both L2 active, $F(1, 609) = 8.44$, $p = .003$, and driver age group, $F(1, 609) = 4.845$, $p = .028$. This indicated that longest glances were longer overall when L2 was active for the L2 NDS drivers, but older drivers' longest glances were shorter than those of the middle-aged L2 NDS participants. Finally, number of off-road glances showed a significant main effect of driver group (lower right panel, **D**), $F(1, 609) = 4.47$, $p = .035$, such that older drivers had fewer glances away from the forward roadway. There was no main effect of L2 active vs. available-but-inactive ($F(1, 609) = 0.043$, $p > 0.05$).

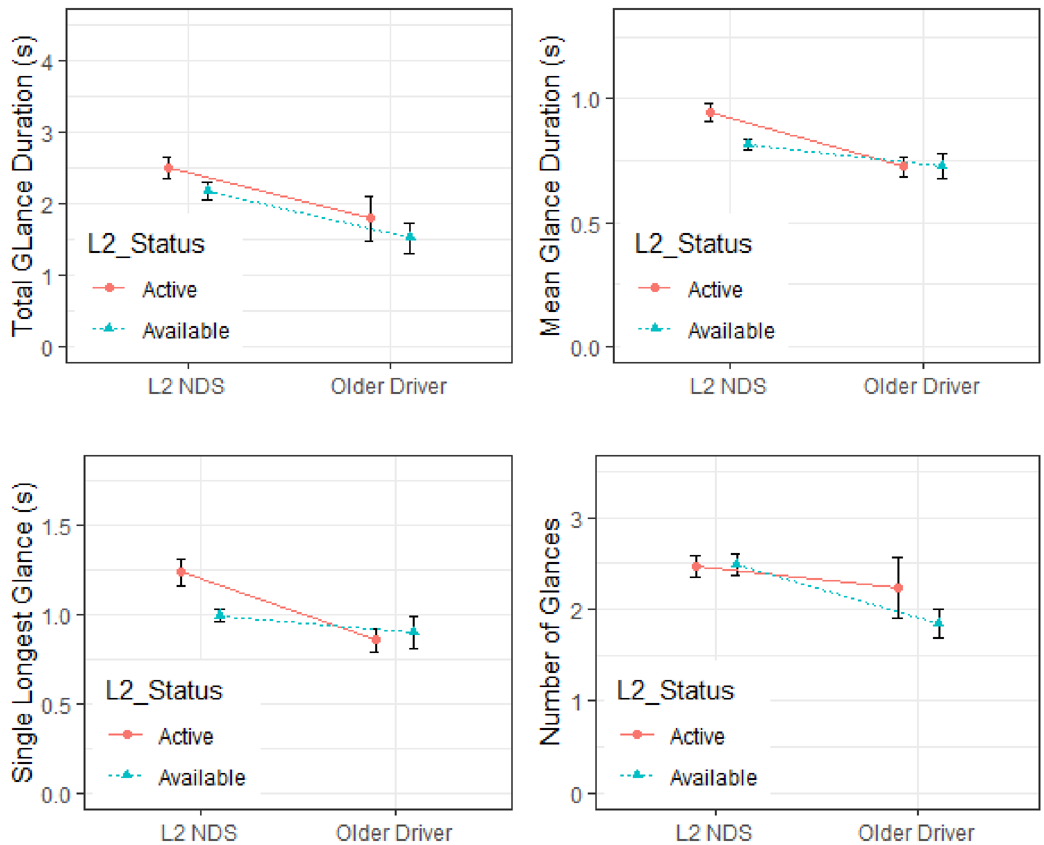

Figure 2. Eye glance metrics for Older Driver NDS vs. L2 NDS participants.

Secondary Task Engagement

Analyses for secondary task engagement were completed using the coded data where samples were randomly selected based upon whether L2 systems were active or available-but-inactive. Older adult drivers were significantly less likely to engage in secondary tasks when L2 was active compared to their middle-aged counterparts in the L2 NDS drivers, χ^2 (1, N = 792) = 4.22, p = 0.04. There were five categories of distraction compared between the two datasets: visual, manual, visual manual, cognitive, and no distraction. See Figure 3 for the percentage of each type of distraction observed in both datasets across L2 active and L2 available-but-inactive samples.

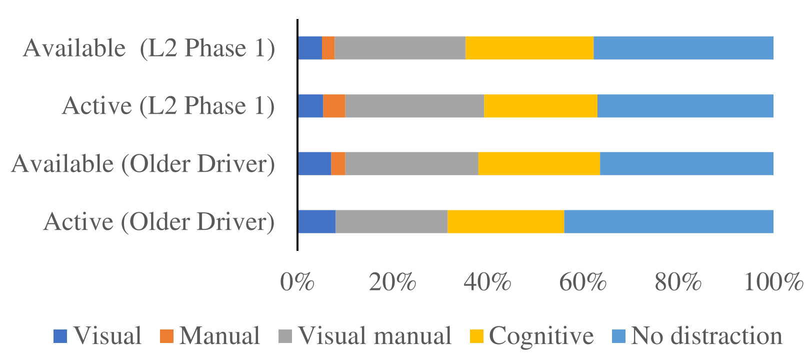

Figure 3. Secondary task distribution percentages comparison by L2 status and participant group (Older Driver vs. L2 NDS Phase 1).

Discussion

Speeding behavior results showed that older adults were more likely to speed with the L2 systems active compared with when they were available-but-inactive. This could demonstrate risk allostasis, wherein drivers are adjusting their behaviors to maintain a preferred level of risk when they perceive that active systems are safe and provide a protective effect. This may also represent drivers perceiving greater risk when systems were available but inactive, where they attend more to the roadway and drive more slowly or cautiously. Alternately, this could be a related to design (e.g., the default settings), where systems let ACC deviate above the posted speed and to set follow distances that may not match the driver's personal driving style. While a separate analysis from the L2 NDS study showed that middle-aged drivers selected increasingly higher speeds over time, older drivers did not use L2 ADAS feature more than 3 hours, which may reduce changes associated with time and allow for the impact of default settings in this demographic.

The glance analyses paint a clear picture. Older adult drivers demonstrated eyes-off-road glance patterns which were shorter in overall, mean, and longest-single glance duration, and the older drivers looked away from the forward roadway less frequently. This coincides with past research (prior to the L2 era) which has shown that older drivers scan less or have a narrower gaze dispersion in certain driving scenarios (e.g., intersection traversals, [9]). Following on this work, researchers examined several underlying conditions which might explain why older drivers demonstrate a more focused scan pattern at intersections. These included head movement limitations, memory-related issues, and distractibility. However, they found that none of these fully explained the observed behavior. Instead, they determined that the propensity was, in effect, older drivers' conscious (or unconscious) attempts to adapt to their own perceived functional decrements. The fact that this behavior also had potentially maladaptive consequences (i.e., missed emergency cues outside of the direct forward view) was unknown to the older drivers [10]. From a transportation safety perspective, these results and conceptualizations present a conundrum. On the one hand, we might interpret the glance behaviors observed in this study as older drivers demonstrating generally greater caution and less distraction, perhaps based on their greater maturity, experience, and very low risk tolerance. However, the research noted above by Romoser and his colleagues paints a different picture, wherein older adults demonstrate a glance pattern that may be too focused or narrow to effectively detect important emergency cues that may appear in the periphery. However, in the current study, an eyes-off-road glance was defined as one not directed to any of the following locations: forward, left window/mirror, left windshield, rearview mirror, right window/mirror, right windshield, or the instrument cluster. Thus, the phenomenon noted by Romoser and colleagues may be fundamentally different than the findings reported in the current study.

While the small sample size for older drivers can be problematic, the secondary task analysis from this study also indicates that older drivers behave more cautiously than their younger counterparts during L2 activation, demonstrating not only a lower percentage of visual and/or manual secondary task time, but also a greater percentage of time with no secondary task of any kind. When the secondary tasks were broken out by low versus high risk, the pattern was less clear, as the older drivers engaged in low-risk tasks during L2 activation at a lower percentage than their younger counterparts; both groups engaged in high-risk tasks at the same percentage. It should be noted that the designation of secondary tasks into low and high-risk categories is based on tasks and driving data observed or collected in the pre-L2 era. While L2 technology may improve safety, the risk levels of specific secondary tasks while L2 is active must be investigated empirically (i.e., considering risk allostasis).

LIMITATIONS

Participants in the L2 NDS were assumed to have little to no previous experience with L2 features. This is an assumption, in that researchers knew that participants had never driven the make/model of the instrumented vehicle assigned to them for data collection, and thus the specific L2 features were novel. While the drivers in these two studies drove a similar set of vehicle make/models, there were differences in how the various OEMs implemented the L2 technologies that were not directly tested or compared in these analyses.

The two datasets were collected in two different regions and driving environments. The L2 NDS drivers were commuters in the Washington, DC area, whereas participants in the Older Driver NDS were residents of a largely suburban and rural area of Blacksburg, Virginia. Thus, the driving environments that these two sets of drivers negotiated were different, and it is impossible to control for this difference in the analyses. While the vehicles in the L2 NDS and Older Driver NDS were similar, the L2 NDS had more variety of vehicles, which may have impacted findings. Another limitation worthy of consideration is that the Older Driver NDS included only a pilot sample of 18 participants, which was smaller than the 82 participants from the L2NDS dataset.

CONCLUSIONS

Evidence of driver adaptation to L2 ADAS may be seen most predominantly in the speed selection analysis. When L2 systems were active, on average, drivers tended to select speeds which were 4.4 mph faster than the average speed driven when the L2 system was available but inactive. In addition, middle-aged drivers (L2 NDS) tended to drive 5.2 mph on average faster than older drivers (Older Driver NDS), but older drivers still selected speeds that were above the speed limit more when L2 ADAS features were active. Speed-selection is related to only one aspect of L2 control, which is often available for independent use as well (such as in the form of Adaptive Cruise Control). The analyzed datasets did not have sufficient instances where L2 was available but only ACC was engaged to be included in speed-selection analysis. Therefore, it is unknown if or how much of the observed effects in speed-selection may be due to the ACC feature use versus L2 use. The result may also be confounded by the possibility that drivers may be more likely to engage L2 features when conditions are generally supportive of speeds higher than the posted limits (e.g., free-flowing controlled-access roads). Thus, it is unclear whether any driver adaptation was observed in these analyses. It is possible that more complete or robust behavioral adaptation to these technologies would take several months, rather than weeks, especially as L2 features may be used infrequently (i.e., on less frequent, longer trips, as opposed to much shorter daily errands). Still, the results are useful in providing insight into how older drivers use L2 systems during the first 3 hours of cumulative use.

REFERENCES

1. Wilde, G. J. (1982). The theory of risk homeostasis: implications for safety and health. *Risk analysis*, *2*(4), 209-225.Wilde, 1982
2. Wilde, G. J. (1982). Critical issues in risk homeostasis theory. *Risk analysis*, *2*(4), 249-258.
3. Kinnear, N. A., & Helman, S. (2013). Updating risk allostasis theory to better understand behavioural adaptation. *Behavioural adaptation and road safety*, 87-110.
4. Antin, J. F., Guo, F., Fang, Y., Dingus, T. A., Hankey, J. M., and Perez, M. A. (2017). The influence of functional health on seniors' driving risk. Journal of Transport & Health, 6, 237-44. https://doi.org/10.1016/j.jth.2017.07.003
5. Kaber, D., Zhang, Y., Jin, S., Mosaly, P., & Garner, M. (2012). Effects of hazard exposure and roadway complexity on young and older driver situation awareness and performance. *Transportation research part F: traffic psychology and behaviour*, *15*(5), 600-611.
6. Liang, D., Lau, N., Baker, S., and Antin, J. F. (2020). Examining senior drivers' attitudes towards advanced driver assistance systems after naturalistic exposure. *Innovation in Aging*, *4*(3), 1-12. https://doi.org/10.1093/geroni/igaa017
7. Liang, D., Antin, J. F., and Lau, N. (2019). Examining Senior Drivers' Acceptance to Advanced Driver Assistance Systems. Presentation delivered at The 5th International Symposium on Future Active Safety Technology toward Zero Accidents (FAST-zero-19), Blacksburg, Virginia, 9/9-11/2019.
8. Russell, S.M., Blanco, M., Atwood, J., Schaudt, W.A., Fitchett, V.L., & Tidwell, S. (2018) Naturalistic study of Level 2 driving automation functions (Report No. DOT HS 812 642). Washington, DC: National Highway Traffic Safety Administration.
9. Romoser, M. R. E. and Fisher, D. L. (2009). The effect of active versus passive training strategies on improving older drivers' scanning in intersections. *Human Factors*, *51*(5), 652-68.
10. Romoser, M. R. E., Pollatsek, A., Fisher, D. L., and Williams, C. C. (2013). Comparing the glance patterns of older versus younger experienced drivers: Scanning for hazards while approaching and entering the intersection. Transportation Research Part F: Traffic Psychology and Behaviour, 16, 104-16.