DMITRY KALINOVSKY/SHUTTERSTOCK

Unsafe Driver Glances at Roadside Unmanned Aerial System Operations

By Zachary Barlow, Alden Sova, David S. Hurwitz, Ph.D. (F), and Michael J. Olsen, Ph.D.

Recent technological advances have made unmanned aerial systems (UASs)—commonly referred to as drones—smaller, more affordable, and more available for civilian operations.[1] As UASs become more ubiquitous in applications for industry, agriculture, and transportation, they will inevitably interact with existing roadway infrastructure. Current commercial, governmental, and research operations are subject to Part 107 of Federal Aviation Administration (FAA) regulations.[2] This policy regulates commercial (non-hobby) UAS use, including pilot responsibilities, operational limitations, and aircraft requirements. The portion of these rules related to roadway infrastructure (Part 107.39) does not allow pilots to operate a UAS directly over moving vehicles. In addition, some states have passed laws related to limiting UAS operations near enclosed critical infrastructure facilities (e.g., water treatment plants). Additional legislation allows for law enforcement and other state government agencies to operate UASs.[3] While not an exhaustive list, such legislation is indicative of state efforts to adapt to this disruptive technology as the legal landscape continues to evolve.

As UAS use increases, so do the potential risks around roadway infrastructure. A 2017 survey of 435 U.S. officials in transportation, law enforcement, and emergency management in 45 states and 98 cities found that UAS use near roadways is a common problem, with more than 21 percent reporting UAS operations close to roadways and traffic. Ninety-two percent of respondents to the survey denoted driver distraction as a potential hazard associated with UAS operations near roadways.[4]

A UAS operation near the roadside would constitute a dynamic external distraction to a driver. External distractions of all kinds account for 29 percent of crashes in the United States.[5] Driving simulator studies are a useful tool to measure the effect of dynamic roadside distractions within a safe environment. Such studies have examined how drivers are distracted by dynamic roadside elements such as digital billboards and wind farms.[6, 7]

Visual distractions can increase crash/near-crash risk for drivers. A study sponsored by the National Highway Traffic Safety Administration (NHTSA) on data from the 100 Car Naturalistic Driving Study of adult drivers found that glances off the road of greater than two seconds doubles the risk of a crash or near-crash from normal driving.[8] The analysis explored time-to-collision values of two seconds or less from the instrumented vehicles in their study. Therefore, the duration of a greater than two-second glance is a quantifiable benchmark of higher risk associated with an external distractor that take the driver's eyes off the road.

The increased use of UASs, particularly near roadways, is a current and growing safety issue for drivers. This study provides observations and quantification of the visual distraction of UAS operations in different scenarios near the roadside through a driving simulator experiment. Specifically, the study evaluated the effect of land use (urban vs. rural), lateral offset, and flight pattern on driver distraction.

Methods

To observe and quantify the level of distraction to motorists due to UASs, an experiment was designed and conducted in the Oregon State University Driving Simulator. This high fidelity driving simulator from Realtime Technologies consists of a 2009 Ford Fusion cab mounted on a pitch motion system with a three panel, 180-degree projected front display and additional LCD and projected screens for the side and rearview mirrors. In addition, the visual attention of the drivers in the simulator was recorded with a Mobile Eye-XG platform from Applied Science Laboratories. The simulator and the eye tracking equipment are shown in Figure 1. A technical report published by the Oregon Department of Transportation includes a more detailed description of the methodology used in the driving simulator portion of this research.[9]

Next, a standard UAS operation was programmed into the simulator, a rendering of which is shown in Figure 2. FAA policies recommend that UASs be operated by a pilot and a spotter and require that the pilot and the spotter be within line-of-sight of the UAS operation at all times.[2] A standard UAS operation consisting of a three-foot square (1 meter) by six-inch tall (15 centimeter) quadcopter style vehicle placed near two avatars representing the pilot and the spotter was used in the simulator. The UAS operations were placed in the environment such that the participants would approach the operation on a tangent segment of road.

A within-groups counterbalanced and partially randomized factorial experimental design was implemented to individually explore three different independent variables to determine specific situations common to UAS operations that could result in visual distractions. The first independent variable was the land use surrounding the UAS operation. The second variable was the lateral offset, or distance of the UAS operation from the edge of the

Figure 1. The Mobile Eye-XG platform (left) and Oregon State University driving simulator (right).

Table 1. Summary of scenarios considered including independent variables and associated levels.

Variable	Level	Name	Description
Land Use	1	Rural	A two lane roadway with light residential and agricultural roadside development
	2	Urban	A four lane, non-divided roadway with medium density commercial and industrial roadside development
Lateral Offset	1	0 ft.	UAS operators and center of vehicle flight pattern located immediately adjacent to the paved shoulder
	2	25 ft.	UAS operators and center of vehicle flight pattern located 25 ft. from the right edge of pavement
	3	50 ft.	UAS operators and center of vehicle flight pattern located 50 ft. from the right edge of pavement
Flight Pattern	1	Takeoff	A UAS vehicle travelling directly upward from the ground to 6 ft. above the ground as the driver passed
	2	Scanning	A UAS vehicle travelling in a slow, zig-zag pattern 32 feet above the ground as the driver passed
	3	Racing	A UAS vehicle travelling in a quick, erratic pattern in three dimensions (averaging 26 ft. above the ground) as the driver passed

road. The flight pattern of the UAS vehicle was the final variable examined. A summary of the variables and their levels is provided in Table 1.

Eye tracking results were collected for 30 participants who were each exposed to all 18 of the UAS operation scenarios over the course of a 20 to 30-minute drive. Of the 30 participants, 16 were male and 14 were female. The average age was 29.4 years, with a minimum age of 18 and a maximum age of 70. Following the collection of data, visual attention data were reduced using *ETAnalysis* software from Argus Science. An area of interest (AOI) was drawn around each UAS operation, encompassing the vehicle, the pilot, and the spotter.

The visual attention of the subjects was a record of their eye movements calibrated to correspond to where the subject was gazing within their field of view. Eye movement consists of fixations and saccades. Fixations occur when the subject's gaze is directed towards a single location and remains still for some period. Saccades are the eye movements between fixations.[10, 11] Sequential eye fixations and saccades within the AOI constitute a single dwell time and indicate a glance off the road toward the UAS operation. A participant could generate more than one dwell per UAS encounter. For example, if a participant glanced at the UAS operation for

Figure 2. Standard UAS configuration of a quadcopter, a pilot, and a spotter in the urban condition (left) and the rural condition (right).

one second and back at the road for one second before returning to glance at the UAS for 1.5 seconds, two separate dwells with a maximum dwell on the UAS of 1.5 seconds are recorded.

Results

After data were reduced, the individual dwells for each of the 18 scenarios were compiled. In total, there were 933 dwells on the UAS operation scenarios across all 18 scenarios for all subjects. These results indicate that each time a driver encountered a UAS operation, they glanced an average of 1.5 times, with the number of glances ranging from 0 to 8 per encounter. However, as was discussed in the introduction, it is the length of glances, not necessarily the frequency, which has been shown to increase crash/near-crash risk. For this study, a glance of greater than two seconds is considered a "long" glance.[8] Figure 3 plots all 933 dwells by length of dwell for each scenario. The red line indicates a dwell time of two seconds, and the observations in the figure above the red line indicate continuous glances off the road of greater than two seconds. Across all 18 scenarios, there were 106 individual glances greater than two seconds in duration.

The speed limit set in the experiment was 35 miles per hour (mph) (56 kilometers per hour [km/hr]) (indicated to participants by roadside speed limit signs), meaning that subjects travelled more than 100 feet (ft.) (30.48 meters [m]) during a two second glance off the roadway. The average speed of participants in the experiment was 38.6 mph (62.1 km/hr), resulting in an even further travel distance during the glance off the road. The average speed did not change as participants approached the UAS operations.

Figure 4 summarizes the 106 dwells of greater than two seconds indicating riskier glances off the roadway. The figure divides the glances based on each of the three independent variables: land use, lateral offset, and flight pattern.

For the land use independent variable, UAS operations in the rural environment caused 68 percent of the long glances, while

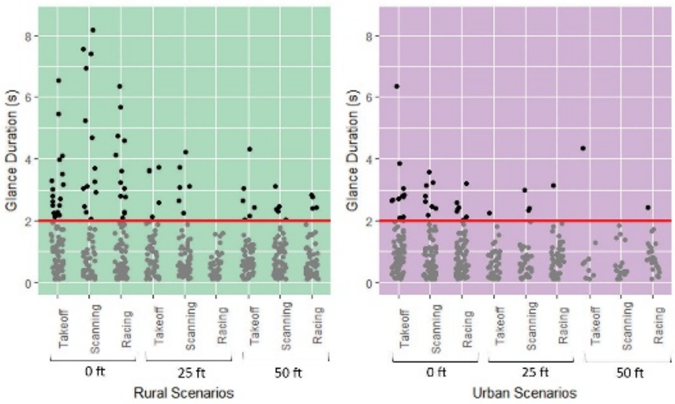

Figure 3. Summary of all dwells by dwell duration for each of the 9 rural and 9 urban UAS operation scenarios.

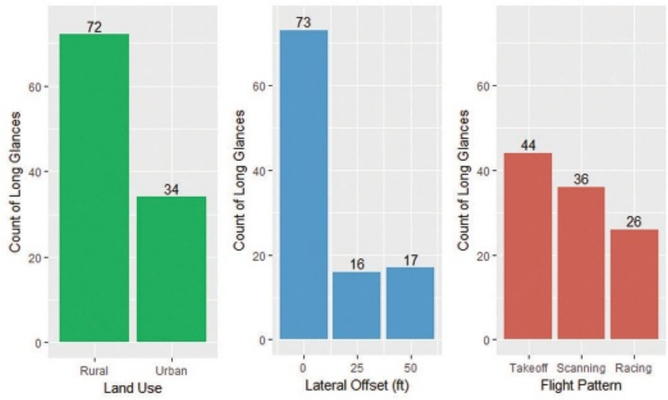

Figure 4. Summary of long glances (>two seconds) for each of the independent variables.

the urban environment generated 32 percent. For the lateral offset variable, 69 percent of the long glances occurred at the 0 ft. offset. The 25 ft. (7.62 m) and the 50 ft. (15.24 m) offsets generated 15 percent and 16 percent of the long glances, respectively. The variable of UAS flight pattern showed a less apparent pattern than the other two independent variables. The takeoff flight pattern generated 41 percent of the long glances, which was moderately higher than the 34 percent for the scanning pattern and 25 percent for the racing pattern. The racing flight pattern may have resulted in less visual attention than the takeoff or scanning flight patterns because the racing pattern was quicker and more erratic, making it potentially more challenging for the participant to glance at for a long time.

Participants were asked in a post-drive questionnaire if they had ever seen a UAS while driving prior to the experiment. Seven of the 30 participants noted that they had seen a UAS while driving. The participants who had previously seen a UAS operation while driving averaged 55 percent more glances of greater than 2 seconds at the UAS operations than those who had not previously seen a UAS while driving. Nevertheless, the sample size for the number of participants who had previously seen a UAS while driving is too small to make any definitive conclusions, but there is a possibility that drivers who have previously seen a UAS while driving are more likely to glance toward UAS operations.

Conclusion

UAS operations near roadway facilities are a current reality and will only increase in frequency as UAS applications and technology evolve. Because these systems are new and evolving rapidly, no studies to date have quantitatively explored the direct risk to drivers from being distracted by UAS operations near roadway infrastructure.

In exploration of this developing topic this study provides empirical data to validate concerns of the 92 percent of survey respondents in the Kim et al.[4] study that indicated they saw driver distraction as a risk of UAS operations near roadways. Using a driving simulator and eye tracking equipment to safely explore the visual attention of drivers exposed to roadside UAS operations, it was found that UAS operations can induce risky eyes-off-road glances.

The presence of UAS operations induced risky glances across exposure scenarios in this study. Seventy percent of participants in this experiment glanced away from the road toward at least one UAS operation for more than two seconds. Using the Klauer et al.[8] threshold, these participants more than doubled their crash/near-crash risk through this action. Some of these long glances may have been even more risky, as multiple subjects had an eyes-off-road glance of more than 7 seconds. At 35 mph (56 km/hr), the subjects travelled more than 350 ft. (106.68 m) without looking at the road.

These long glances occurred across all levels of the independent variables in this study's factorial design. This study indicates that UAS use within 50 ft. (15.24 m) of a roadway can induce risky glances from drivers in rural and urban roadside environments. It is also possible that UAS operations can result in visual distraction further from the roadside, though this study only examined operations up to 50 ft. (15.24 m) from the road edge. Within the 50 ft. (15.24 m) threshold, a key finding is the higher chance of long glances at UAS operations occurring in rural environments. The rural environment, which lacks the buildings and other roadside facilities of the urban environment, provides the driver with a more unobstructed line of sight to roadside activities. The UAS operations are more conspicuous and are visible to the driver for a longer timeframe, possibly explaining why more long glances occurred in the rural environment.

In summary, the results of this experiment in a driving simulator environment indicate UAS use near roadway infrastructure may have the potential to cause drivers to make risky eye-off-road glances toward the UAS operations, especially when the UAS operation occurs immediately adjacent to the roadside or is in a rural environment. UAS operations near roadways is an emerging field of research, and additional studies will need to be conducted to more fully understand the challenges and risks associated with UAS operations. However, transportation officials need to be aware of the potential risks of UAS operations adjacent to roadways as UASs emerge more frequently in environments near roadway infrastructure.

Acknowledgments

Material in this paper is based on work supported by the Oregon Department of Transportation (ODOT) under Agreement #31167–Project 3. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the ODOT. Richie Slocum and Corey Barlow assisted in the modeling of the UAS vehicle for this experiment, and the Oregon State Center for Healthy Aging Research's Life Registry supported participant recruitment.

References

1. R. Clarke, "Understanding the Drone Epidemic," *Computer Law Security Review*, vol. 30, no. 3, pp. 230–246, Jun. 2014.
2. "Small Unmanned Aircraft Systems," U.S. Department of Transportation Federal Aviation Administration, 14 C.F.R §107, 2016.
3. "Drones and Critical Infrastructure," National Conference of State Legislatures, 2018. http://www.ncsl.org/research/transportation/current-unmanned-aircraft-state-law-landscape.aspx. Accessed: June 11, 2018.
4. K. Kim, R. Uyeno, P. Pant, E. Yamashita, and J. Ghimire, "Drones and Traffic Safety: Preliminary Risk Assessment," Transportation Research Board, 2017, pp. 1–18.
5. J. Stutts, D. W. Reinfurt, L. Staplin, and E. A. Rodgman, "The Role of Driver Distraction in Traffic Crashes," AAA Foundation for Traffic Safety, 2001.
6. S. Milloy and J. Caird, "External Driver Distractions: The Effects of Video Billboards and Wind Farms on Driving Performance," *Handbook of Driving Simulation for Engineering, Medicine, and Psychology*, Boca Raton, FL: Taylor & Francis, 2009, p. 16.1–16.4.
7. D. Stavrinos, P. R. Mosley, S. M. Wittig, H. D. Johnson, J. S. Decker, V. P. Sisiopiku, and S. C. Welburn, "Visual Behavior Differences in Drivers Across the Lifespan: A Digital Billboard Simulator Study," *Transportation Research Part F. Traffic Psychol. Behavior*, vol. 41, no. A, pp. 19–28, Aug. 2016.
8. S. G. Klauer, T. A. Dingus, V. L. Neale, J. D. Sudweeks, and D. J. Ramsey, "The Impact of Driver Inattention On Near-Crash/Crash Risk: An Analysis Using the 100-Car Naturalistic Driving Study Data," Washington, DC, 2006.
9. D. Hurwitz, M. Olsen, and Z. Barlow, "Driving Distraction Due to Drones," Salem, OR, 2018.
10. P. Green, "Where Do Drivers Look While Driving (and for How Long)?," *Human Factors in Traffic Safety*, 2nd edition, Tucson, AZ: Lawyers & Judges Publishing, 2007, pp. 57–82.
11. D. Fisher, M. Rizzo, and J. Caird, *Handbook of Driving Simulation for Engineering, Medicine, and Psychology*. Boca Raton, FL: CRC Press, 2011.

Zachary Barlow *is a Ph.D. candidate in civil engineering at Oregon State University (OSU). He received a bachelor's degree in civil engineering from Virginia Tech and a master of science in civil engineering from OSU. His research broadly explores rural transportation safety, with an emphasis on safety and human factors in rural roadway construction and maintenance activities.*

Alden Sova *is an undergraduate research assistant pursuing an honors degree in industrial engineering at Oregon State University. His research focuses on rural transportation safety and driver distraction, especially as affected by near-roadway drone operations. His focus within industrial engineering is in operations engineering and management.*

David S. Hurwitz, Ph.D. (F) *is an associate professor of civil engineering and director of the Driving and Bicycling Simulator Laboratory at Oregon State University (OSU). Dr. Hurwitz conducts research, teaches classes, and serves on a variety of national committees in the areas of transportation operations and safety with a particular focus on transportation human factors. Dr. Hurwitz is an active Fellow of ITE and Advisor of the OSU ITE Student Chapter.*

Michael J. Olsen *is an associate professor of geomatics in the School of Civil and Construction Engineering at Oregon State University. He is currently serving as the editor-in-chief for the American Society of Civil Engineers* Journal of Surveying Engineering. *He received a B.S. and M.S. in civil engineering from the University of Utah and a Ph.D. in structural engineering from the University of California, San Diego. His current areas of research include terrestrial laser scanning, photogrammetry, geographic information systems, efficient point cloud processing algorithm development, geohazard mapping, monitoring and analysis, and 3D visualization.*