Can the Acoustic Starting Pre-Stimulus Reduce Take-Over Time in Critical Autonomous Driving Scenarios?

M.K. Griffith[1,2], J. Maheshwari[1], R. Akkem[1,3], T. Seacrist[1], K.B. Arbogast[1], and V. Graci[1]
[1] Center for Injury Research and Prevention, Children's Hospital of Philadelphia; [2] School of Engineering and Applied Science, University of Pennsylvania; [3]College of Engineering, Drexel University

ABSTRACT

In highly autonomous driving scenarios, it is critical to identify strategies to accelerate reaction times since drivers may take too long to take-over control of the vehicle. Acoustic Startling Pre-stimulus (ASPS, i.e. a loud sound preceding an action) was found to accelerate reaction times in flexion exercises. In this study, we examined if ASPS warning leads to shorter take-over reaction times in a sled-simulated autonomous driving scenario. Seven adult (25-37 y.o.) and seven teenage (17 y.o.) male participants were instructed to align a marker on the steering wheel with a marker on a lateral post as fast as they could as soon as lateral sled perturbation started (0.75 g). Five conditions were examined: with and without an ASPS (105 dB, played 250 ms before sled perturbation for 40 ms), with and without a secondary task (i.e. texting), and a catch trial (ASPS only) to minimize anticipation. Human kinematics were collected with an 8-camera 3D motion capture system. Results showed that adults lift their hand toward the steering wheel more quickly with the ASPS (161 ± 23 ms) than without (216 ± 27 ms) ($p<0.003$) but not in the texting trials. Teenage drivers did not show any effect ($p>0.1$). This suggests that ASPS may be useful early in the corrective action performed during an evasive maneuver for male adult drivers.

INTRODUCTION

Motor vehicle crashes are the leading cause of death for teens and among the leading causes of death for adults (CDC, 2019). Furthermore, distracted driving is a leading cause of motor vehicle crashes, particularly for teenage drivers (NHTSA, 2018). As autonomous vehicles become a reality, there is a greater potential for driver distraction due to the reduced task load for the human driver. Previous studies examining the effect of boredom in operators of unmanned aerial vehicles showed that the both the time spent in a distracted state and reaction times to events increased as the task load decreased (Cummings, 2014). However, in a highly autonomous driving scenario it may become necessary for a driver to take over control of the vehicle in order to perform a crash avoidance maneuver. Studies found that, in autonomous driving scenarios, drivers may take too long to take over control of the vehicle; moreover, drivers took even longer to resume control of the vehicle when engaged in a secondary task (Eriksson, 2017). Whether the driver is distracted or not, a long reaction time may be detrimental to crash avoidance. It is therefore important to identify strategies to accelerate reaction times to minimize the risk and the severity of crash events.

A number of previous studies have looked at how different in-vehicle warning systems affect reaction times and driver perceptions. Studies in take-over requests in automated driving showed that combined visual and auditory warnings were shown to reduce hands on wheel time more than purely visual warnings (Naujoks, 2014). In manual driving scenarios studying forward collision warnings (FCW), careful selection of acoustic criteria including peak-to-total-time ratio, interburst interval, number of harmonics, frequency, and pulse duration were shown to significantly improve the efficacy of auditory warnings (Lewis, 2017). Other studies showed that ambient noise conditions, as found in many realistic driving scenarios, could change the perceived urgency and meaning of auditory signals (Lerner, 2015). Some of these previous studies testing the efficacy of warning systems are limited, however, by use of driving simulators. In such studies, the driver does not experience a real physical perturbation, which may cause a startle reflex (Sanders, 2015) and alter the drivers' take-over reaction time.

Previous studies on warning systems have not accounted for physiological phenomena such as the startle reflex, which may influence driver reaction times. Startle responses are neuromuscular body reactions to intense stimuli. According to Mang et al (2012), startle evoked by a rear-end collision may contribute to whiplash injuries; however, evoking an earlier startle response before the collision reduced the startle response caused by the collision and reduced head acceleration that may cause whiplash injuries (Mang, 2012). An effective starting stimulus that can evoke an earlier startle response was determined to be an Acoustic Startling Pre-Stimulus (ASPS), which is defined as a 105 dB sound preceding the sled perturbation by 250 ms (Mang, 2012). Sutter and colleagues found that the ASPS could accelerate prepared, unpracticed movements such as ankle flexion exercises (Sutter, 2016). Therefore the ASPS may potentially reduce take-over reaction times and accelerate corrective actions in a critical autonomous driving scenario.

Previous studies have shown that startle reactivity is greater at younger ages, but did not consider teenagers in their study design (Ludewig, 2003). According to the CDC, the risk of motor vehicle crashes is higher for teenagers than any other age group (CDC, 2018), and recognition errors such as inadequate surveillance and distraction were found to be the leading cause of crashes among teenage drivers (Curry, 2011). Furthermore, teenagers have been clearly shown to take more risks than any other age group, though the psychology of why they are more prone to risky behavior is less clear (Steinberg, 2007). The differences in the ability to take-over in teenage versus adult drivers are unclear, although it is known that young drivers tend to deactivate in-vehicle warnings (Montgomery, 2014). The FCW and Lane Departure Warnings (LDW) activate around 1.7-2 s and 3-4 s respectively before time of collision (TTC). Young drivers tend to keep a closer distance with the other vehicles and therefore trigger nuisance warning alarms, which lead them to deactivate FCW and/or LDW (Montgomery, 2014). Therefore ASPS take-over request warnings may potentially be beneficial since it consists of a single beep that activates 250 ms before the pre-crash maneuver starts and therefore may not trigger nuisance alarms

Therefore, the primary aim of this study is to examine if take-over reaction times to reach and turn the steering wheel to deploy a corrective action during swerving is decreased by the ASPS. A secondary aim of this study is to understand how drivers respond to the ASPS when they are not ready to react but they are engaged in a secondary task. A third final aim is to compare adult vs teenage drivers in their responses to the ASPS to understand if ASPS is influenced by the effect of age.

METHODS

The study protocol was reviewed and approved by the Institutional Review Board of The Ohio State University and the Children's Hospital of Philadelphia.

Participants

Seven adult (ages 25 – 37 years, height 177.9 ± 6.0 cm, weight 78.0 ± 12.9 kg) and seven teenage (age 17 years, height 175.0 ± 7.0 cm, weight 68.4 ± 7.3 kg) healthy male drivers participated in the study. In order to be included in the study, participants' BMI had to be between the 5^{th} and 95^{th} percentile according to the subject's age and they needed to hold a valid driver's license. Teenagers were included if they had driven at least 12 hours in the previous 12 months, in addition to that adults also had to have at least 5 years of driving experience to be eligible.

Sled Apparatus

A custom sled apparatus exposed subjects to low-severity, non-injurious loading conditions that mimic pre-crash swerving events (Holt, 2017). The lateral sled perturbation is similar to an evasive emergency swerve and has a peak acceleration of approximately 0.75 g. One oscillatory movement (i.e. cycle) was provided, and it consisted of a right swerve (driver's motion into the belt) followed by a left swerve (driver's motion out of the belt).

Figure 1: Custom sled apparatus

Three lightweight belt webbing load cells (6200FL-4130, Denton ATD Inc, Rochester Hills, MI) were installed on the shoulder belt (between the subject and the D-ring location) and the right and left lap belt. The load cell data were sampled at 10,000 Hz using an onboard T-DAS data acquisition system (T-DAS Pro, DTS Inc, Seal Beach, CA).

The occupant compartment included three onboard GoPro HERO Session 4 cameras. One was oriented in the overhead perspective of the volunteers, one was oriented in the frontal perspective of the volunteers, and the last was oriented to the volunteers' feet. High-speed 2D video data from these cameras were captured at 30 Hz.

Human Subject Instrumentation

Kinematic data were captured using an on-board Optitrack Prime13W 8-camera motion-capture system (200 Hz, NaturalPoint, Inc., Corvallis, OR). The motion-capture calibration was performed prior to each test session to determine the relative position and field of view of each camera and the global coordinate system.

Volunteers were provided with an athletic compression shirt and a pair of athletic shorts. Once in proper attire photo-reflective markers were placed on participants' head (on a tightly fitted headpiece), trunk (bilateral acromion, suprasternal notch, and xiphoid process), upper extremities (bilateral humeral epicondyle, radial styloid process), and the right foot (Figure 2). For the right foot, suprasternal notch, and the xiphoid process, an array of four markers were placed on rigid structures that were then attached to the skeletal landmark/belt. Other markers were placed on the top of the steering wheel, on the post placed laterally to the steering wheel, on each of the pedals, on the seat, on the seat belt, and on the D-ring.

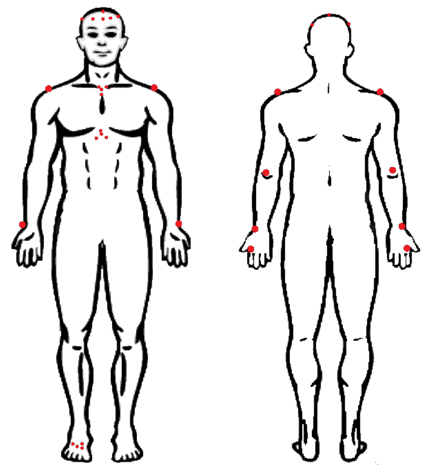


Figure 2: Positions of photo-reflective markers on subjects. Head markers, suprasternal notch, and xiphoid process markers were placed on rigid body structure

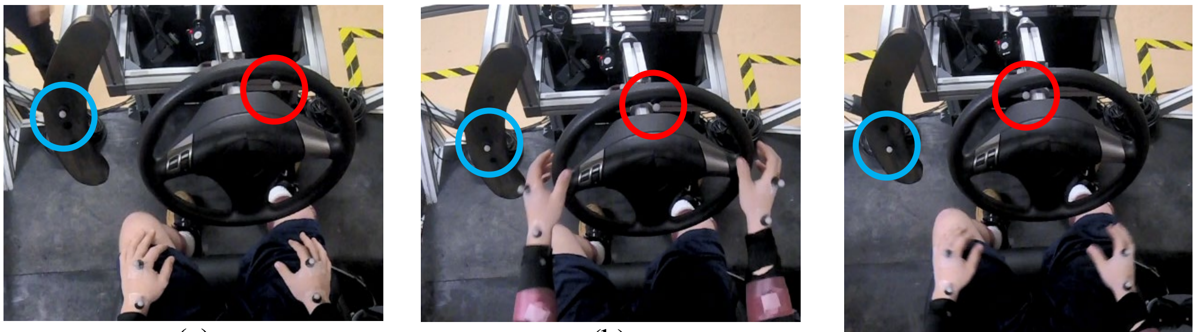
Wireless surface electromyography (EMG) electrodes (Trigno Weireless, Delsys, Natick, MA) were placed bilaterally on the musculature of the neck (i.e. sternocleidomastoids), upper back (i.e. middle trapezoids), lower extremities (i.e. soleus and tibialis anterioris), and upper extremities (Deltoids, biceps, and brachioradialis).

Experimental Testing

Subjects were then seated in the driver compartment on the sled and restrained with a standard seat belt. The volunteers starting position was non-tensed with their hand in their lap. Participants were told that the task represented a highly autonomous driving scenario where they did not need to keep their hand the steering wheel. No instructions were given about the feet placements in relation to the pedals.

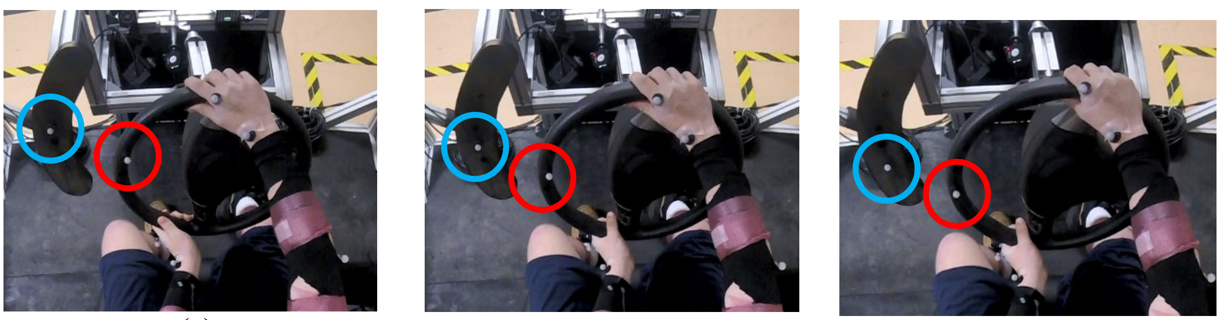
The task volunteers were instructed to perform was to align a photo-reflective marker on the steering wheel with the stationary photo-reflective marker on the lateral post positioned next to the steering wheel. Before each experimental condition, the volunteers were instructed to align the markers as fast as they could and as accurately as they could as soon as they felt the sled moving.

The starting positions of the two markers were randomized between trials between three locations (Figure 3), so that the angle between the two markers referenced to the center of the wheel was always 90 degrees in all three locations, but the three markers locations were varied 4.5 cm far apart from each other (Figure 3). This was done to minimize motor adaption in marker alignment. The small difference between the three marker locations prevented the subjects from employing a different muscle strategy to align the markers across the three marker locations (Figure 4 show similar subject's hand motion for the three marker locations). Prior to testing, while the sled was not activated, subjects were instructed to perform an "alignment trial" for each of the three marker positions at their comfortable speed to establish a working definition of marker alignment for each position (Figure 3,4).



(a) (b) (c)

Figure 3: Initial position of photo-reflective markers on the steering wheel, circled in red, and photo-reflective markers on the lateral post, circled in blue, for each of the three positions.



(a) (b) (c)

Figure 4: Alignment position of photo-reflective markers on the steering wheel, circled in red, and photo-reflective markers on the lateral post, circled in blue, for each of the three positions.

After the three "alignment trials", the participants were exposed to 5 different testing conditions (Table 1) repeated twice in a randomized order. Two of the conditions included the ASPS as a warning occurring 250 ms before the sled motion. The ASPS intensity was 105 dB and lasted for 40 ms (Mang, 2012). Two of the conditions involved a secondary task that consisted of typing a mobile text while the start moving. For the conditions with the texting tasks, subjects were instructed to start typing few seconds before the sled moved. Some examples of texts were listing 10 favorite foods, listing 10 favorite spots in Philadelphia, listing 10 favorite movies, or listing 10 places they would like to visit. The texts were designed so that the subject would have to think about their response while typing and would not finish the text before the sled motion began.

A fifth condition consisting of an ASPS only without sled perturbation was used a catch trial to prevent anticipation of the sled motion. Another way to prevent potential anticipatory effect was the employment of a latency time of a random duration between 1 and 10 seconds between the experimenter instruction, “As soon as the sled start moving, reach for the steering wheel as fast as you can and align the markers as accurately as you can,” and sled activation. This way the participants could not predict when the sled started.

Table 1: Testing conditions, repeated twice in a randomized order

Condition	**Description**
Sled only	Sled perturbation only without ASPS and without Secondary Task
Texting+Sled	Sled perturbation without ASPS but with Secondary Task – sled perturbation occurred while participants sent a mobile text
ASPS+Sled	Sled perturbation with ASPS and without Secondary Task – ASPS (105 dB auditory warning sound lasting 40 ms) was played 250 ms before the sled perturbation started
ASPS+Texting+Sled	Sled perturbation with ASPS and with Secondary Task –ASPS (105 dB auditory warning sound lasting 40 ms) was played 250 ms before the sled perturbation started and while participants typed a mobile text
Catch trial (ASPS only)	ASPS (105 dB auditory warning sound lasting 40 ms)

Data Analysis

Kinematic data from the motion-capture was processed using Motive Tracker software (NatrualPoint, Inc., Corvallis, OR) and then imported into custom-made Matlab (MathWorks 2017, Inc., Natick, MA) programs to extract the relevant kinematic outcome measures for analysis. Position volunteers’ wrists, the steering wheel, and the lateral post were analyzed to identify 5 key parameters that comprehensively quantify the trajectory of the driver’s hands and steering wheel motion from hand lift-off to markers’ alignment (Table 2).

Table 2: Dependent measures analyzed to quantify the trajectory of the driver’s hands

Outcome Measure	**Description**
Hand Lift-Off Reaction Time	the time between the onset of the sled motion and the instant at which the wrist velocity was greater than the mean + 0.5 SD of the wrist velocity (Figure 6b). The first hand reaching the velocity threshold defined as such was chosen for this dependent measure
Hand On Wheel Reaction Time	the time from onset of the sled motion and the instant at which the distance between the participants’ index fingers and the steering wheel first reached its minimum, confirmed by video analysis (Figure 5, 6c). The first hand reaching the minimum distance with the steering wheel was chosen for this dependent measure
20° Wheel Angle Time	the time between the onset of the sled motion and the instant at which the steering wheel was at 20 degrees from its original orientation (Figure 5, 6d)
Corrective Time	the time between the Hand On Wheel Reaction Time and the instant at which at which the steering wheel and post markers were aligned

	(Figure 5, 6e). The alignment was defined as the minimum difference between the wheel-post distance in the trial and the wheel-post distance in the alignment trials completed prior to testing.
Accuracy	the minimum difference between the distance from the steering wheel to the lateral post marker in the trial and the distance from the steering wheel to the lateral post marker in the alignment trials completed prior to testing.

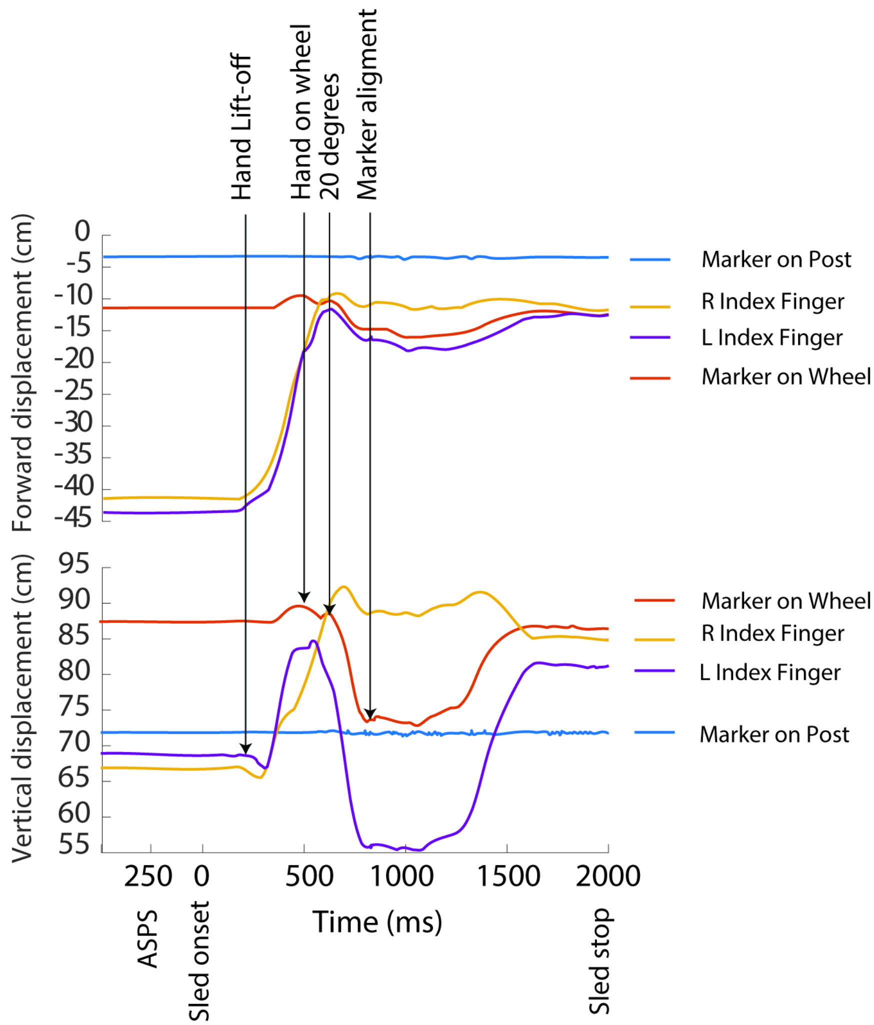


Figure 5: Trajectories of post, steering wheel, left index finger, and right index finger photo-reflective markers during one trial, with dependent measures labeled. Hand Lift-off was actually calculated on the wrist marker trajectory, not displayed here for clarity

(a) (b) (c) (d) (e)

Figure 6: Series of photos, with top and front views, depicting the subjects posture and hand/hands motion: **(a)** subject's initial position before sled perturbation; **(b)** Hand Lift-Off Time Reaction time, at which hand lifts off of participants lap; **(c)** Hand On Wheel Reaction Time, at which participant touches steering wheel; **(d)** 20° Wheel Angle Time, at which participant has turned steering wheel 20 degrees from its initial position; **(e)** Corrective Time, at which participant has aligned the steering wheel and post markers (at which Accuracy measure is also calculated).

A Mixed Repeated Measure 4-way ANOVA was performed to understand the effect of age (adult versus teenager), ASPS (trials with ASPS versus trials without ASPS), Secondary Task (with versus without), and Repetitions (1 versus 2) on the 5 kinematic outcome measures. Post-hoc tests were performed using Tukey's HSD. P-level was set to 0.05.

RESULTS

Hand Lift-Off Reaction Time could be extracted from only 13 subjects due to incomplete wrist marker data in 1 adult subject.

A statistically significant 3-way interaction was found between Age, ASPS, and Secondary Task ($p=0.004$) showing that in the adult subjects, Hand Lift-Off Reaction Time was shorter in the ASPS+Sled condition (161 ± 23 ms) compared to the Sled only condition (216 ± 27 ms) ($p<0.003$). Hand Lift-Off Reaction Time was also shorter in ASPS+Sled than ASPS+Texting+Sled (210 ± 22 ms) ($p<0.01$). In the teenage subjects, there were no significant differences between conditions (p>0.11). Standard deviation in adults decreased in the ASPS+Texting+Sled trials (22 ms) compared to the Texting+Sled trials (55 ms). (Table 3, Figure 7).

Table 3: Age, ASPS, and Secondary Task 3 way interaction effects in Hand Lift-Off Time

	Sled only	**ASPS+Sled**	**Texting+Sled**	**ASPS+Texting+Sled**	**P-Value**
Adult Males Reaction Times (ms)	216 ± 27	161 ± 23	198 ± 55	210 ± 22	ASPS+Sled < Sled only, **p<0.003**; ASPS+Sled < ASPS+Texting+Sled, **p<0.01**
Teenage Males Reaction Times (ms)	179 ± 48	188 ± 37	213 ± 28	213 ± 26	p>0.14

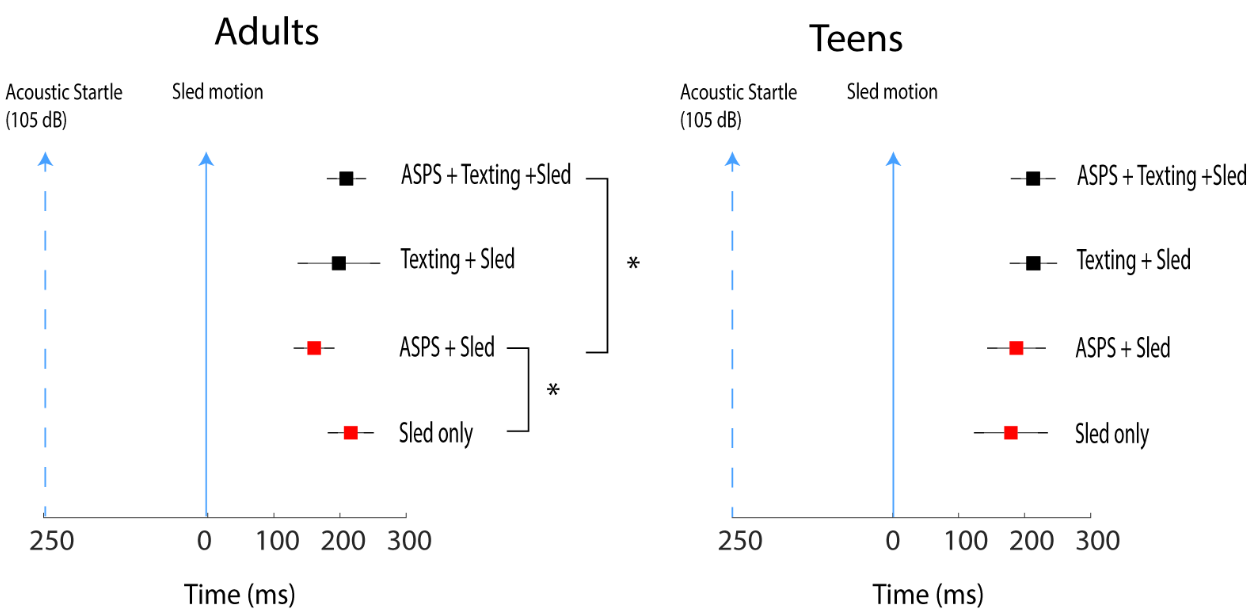


Figure 7: Groups of means and SD of Hand Lift-off Reaction Time in each test condition for two age groups.*p<0.05

Another statistically significant 3-way interaction was found between Age, Secondary Task, and Repetition (p=0.04) showing that in the teenage subjects, the Hand Lift-Off Reaction Time in the first repetition was longer when the subjects were texting (223 ± 26 ms) than when they were not (182 ± 40 ms) (p<0.03) while no differences were found in the second repetition (p=0.51). No significant difference was found in the adult subjects (p>0.24). (Table 4, Figure 8).

Table 4: Age, Secondary Task, and Repetition 3 way interaction effects in Hand Lift-Off Time

	Rep 1	**Rep 2**	**Rep 1 + Texting**	**Rep 2 + Texting**	**3-way interaction p-value**
Adult Males Reaction Times (ms)	200 ± 21	178 ± 31	202 ± 47	206 ± 22	**p>0.25**
Teenage Males Reaction Times (ms)	182 ± 40	185 ± 47	223 ± 26	207 ± 40	Rep 1 < Rep 1 + Texting, **p<0.03**

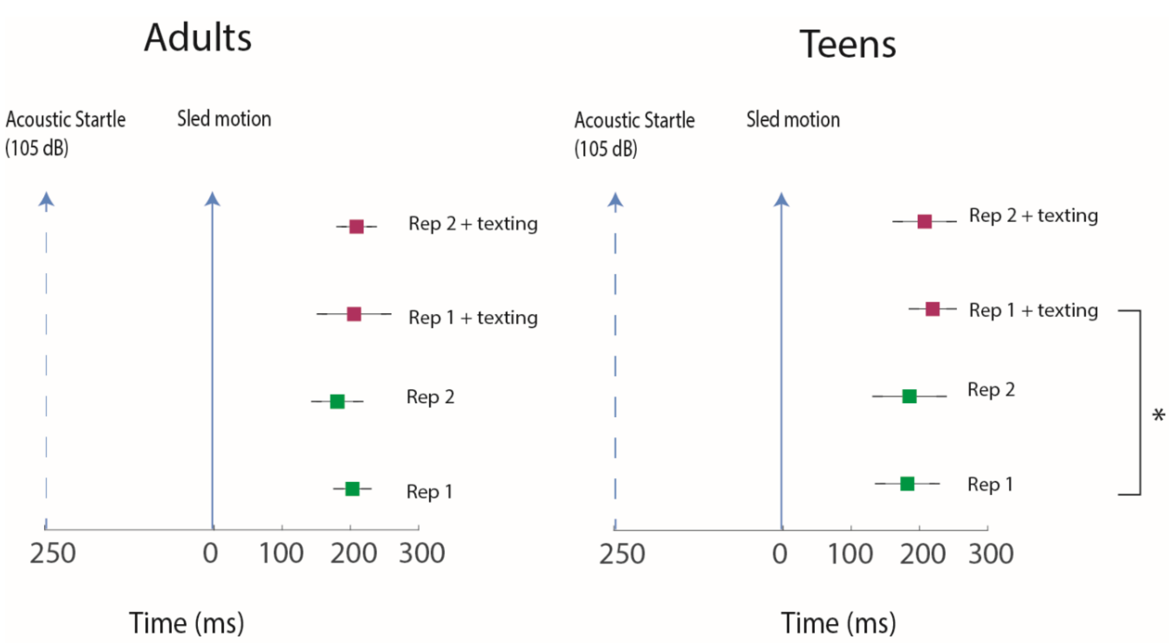


Figure 8: Group of means and SD of Hand Time of lift-off for each repetition of trials with a secondary task and trials without a secondary task for each age group. *p<0.05

A main effect of Secondary Task was found on Hand On Wheel Reaction Time and 20° Wheel Angle Time (p<0.001) and showed that both reaction times were longer in trials with the texting task (475 ± 23 ms and 696 ± 166 ms, respectively) than without (430 ± 41 ms and 538 ± 128 ms, respectively).

Overall, Hand On Wheel Reaction Time was shorter in trials where subjects used two hands (440 ± 60 ms) than in trials where subjects used only one hand (475 ± 12 ms) (p<0.02). Additionally, it was observed that the first hand to reach the steering was not always the same as the first hand to lift off.

A main effect of Secondary Task was also found in the Accuracy of the alignment (p=0.04), which showed that subjects were more accurate in aligning the two markers in trials without the texting task (0.2 cm ± 0.2 cm) than in those with the texting task (0.7 cm ± 0.9 cm).

Although not statistically significant, a trend was found in the differences between age groups in the Corrective Time, showing that adults are quicker in aligning the two markers (770 ± 206 ms) than teenagers (989 ± 206 ms) across all test conditions (p=0.07).

DISCUSSION

The aim of this study was to understand if a novel warning for critical autonomous scenarios based on the startle reflex could reduce take-over reaction times in adult male drivers and teenage male drivers either when they were ready to react and when they were engaged in a mobile texting task. The results showed that when adult male drivers were ready to react, they lifted their hands from their lap on average 55 ms more quickly when exposed to the ASPS. Although 55 ms might not be enough time to avoid a crash completely, it may reduce the severity of the crash and allow the driver to return to an optimal position within the seat-belt and reduce crash-related injuries.

The effect of ASPS was not observed later in the trajectory of the hands. Hence startle appears to have a significant effect only very early in the movement. In trials where the driver only uses one hand to reach the steering wheel, the first hand lifted was not the first hand touching the wheel in 53% of the trials. Furthermore, Hand On Wheel Reaction Time was longer when drivers used only one hand to reach the steering wheel (468 ± 46 ms) compared to when they used both hands (440 ± 65 ms) (p=0.015). These findings suggest that using one hand to reach the steering wheel may be detrimental in take-over actions.

Although when adult male drivers were texting, the ASPS did not decrease their Hand Lift-Off Reaction Time, between-subjects variability in the Secondary Task condition with ASPS was smaller compared to the condition with the Secondary Task and no ASPS. This may suggest that ASPS leads to more consistent take-over reaction timing between drivers.

The effect of ASPS was not observed in the teenage male drivers. A potential explanation could be that the teenage male drivers used only one hand to grab the steering wheel in 57% of trials, which was shown to increase Hand On Wheel Reaction Time; in contrast, the adult male drivers only used one hand to grab the steering wheel in 34% of trials. In agreement with this observation, Corrective Time was also greater in teenage male drivers compared to the adult male drivers (although the difference was not statistically significant, p=0.07). These findings are line with previous investigations that found that teenagers engage in more risky behaviors (Steinberg, 2007) including using cell phones while driving, even at high-risk speeds (McDonald, 2018).

All drivers showed increased reaction and corrective times and poor alignment accuracy in the texting conditions, confirming previous literature that showed that engaging in a secondary task while driving is detrimental to the driver's preparedness to execute a corrective maneuver (Hancock, 2003).

This study had several limitations. Due to the small sample size a tight age range was used for the teenage male population (not older than 17.5 years old) to avoid spurious results due to the variability in driving experience in the group. Therefore we tested only relatively unexperienced drivers. However, it is plausible that the differences in reaction times found between teenage and adult male drivers in our study are likely due to the effect of age since it has been shown that the brain is not fully developed in teenagers (Simmonds, 2017). Another limitation of our study is that we did not give instructions in how to reach the steering wheel (one hand or two hands) since we wanted to understand the natural behavior of the drivers during a critical autonomous scenario. The lack of this instruction has impacted our reaction time since the variability in responses due to the use of one or two hands may have masked the influence of the ASPS in the teen drivers.

CONCLUSIONS

The ASPS warning system was effective in reducing the time for ready-to-react adult male drivers to lift their hands to begin a corrective movement during a swerving maneuver in an autonomous driving scenario. This suggests that ASPS may be useful early in the corrective action performed during an evasive maneuver. Teenage male drivers did not reduce take-over time with the ASPS and they tend to reached for the steering wheel with one hand only increasing their reaction time compared to adult male drivers.

Future work will include the analysis of muscle activity and load distribution to further understand to role of the ASPS in take-over actions.

ACKNOWLEDGEMENTS

The authors acknowledge the National Science Foundation (NSF) Center for Child Injury Prevention Studies IU/CRC at the Children's Hospital of Philadelphia (CHOP) and the Ohio State University (OSU) for sponsoring this study and its Industry Advisory Board (IAB) members for their support, valuable input, and advice. The views presented here are solely those of the authors and not necessarily the views of CHOP, CIRP, OSU, the NSF, or the IAB members.

REFERENCES

CDC. (2018). *Teen Drivers: Gets the Facts*. 3–4. Retrieved from https://www.cdc.gov/motorvehiclesafety/teen_drivers/teendrivers_factshe

CDC. (2019). Leading Causes of Death Reports, 1981-2017. Retrieved from WISQARS Fatal Injury Data website: https://webappa.cdc.gov/sasweb/ncipc/leadcause.html

CUMMINGS, M., MASTRACCHIO, C., THORNBURG, K. M., & ASHOT MKRTCHYAN, A. (2014). Boredom and Distraction in Multiple Unmanned Vehicle Supervisory Control. In *Interacting with Computers* (Vol. 25). https://doi.org/10.1093/iwc/iws011

CURRY, A. E., HAFETZ, J., KALLAN, M. J., WINSTON, F. K., & DURBIN, D. R. (2011). Prevalence of teen driver errors leading to serious motor vehicle crashes. *Accident Analysis* *and Prevention*. https://doi.org/10.1016/j.aap.2010.10.019

ERIKSSON, A., & STANTON, N. A. (2017). Takeover Time in Highly Automated Vehicles: Noncritical Transitions to and From Manual Control. *Human Factors*, *59*(4), 689–705. https://doi.org/10.1177/0018720816685832

HANCOCK, P. A., LESCH, M., & SIMMONS, L. (2003). The distraction effects of phone use during a crucial driving maneuver. *Accident Analysis & Prevention*, *35*(4), 501–514. https://doi.org/https://doi.org/10.1016/S0001-4575(02)00028-3

HOLT, C., SEACRIST, T., GRACI, V., KERRIGAN, J., BALASUBRAMANIAN, S., KENT, R., & ARBOGAST, K. B. (2017). Occupant Torso Kinematics in Low Acceleration Time-Extended Evasive Swerving Events. *Stapp Car Crash Conference*, (4), 13–15.

LEWIS, B. A., EISERT, J. L., & BALDWIN, C. L. (2017). Validation of Essential Acoustic Parameters for Highly Urgent In-Vehicle Collision Warnings. *Human Factors*, *60*(2), 248–261. https://doi.org/10.1177/0018720817742114

LUDEWIG, K., LUDEWIG, S., SEITZ, A., OBRIST, M., GEYER, M. A., & VOLLENWEIDER, F. X. (2003). The acoustic startle reflex and its modulation: effects of age and gender in humans. *Biological Psychology*, *63*(3), 311–323. https://doi.org/https://doi.org/10.1016/S0301-0511(03)00074-7

MANG, D. W. H., SIEGMUND, G. P., INGLIS, J. T., & BLOUIN, J.-S. (2012). The startle response during whiplash: a protective or harmful response? *Journal of Applied Physiology*, *113*(4), 532 LP – 540. Retrieved from http://jap.physiology.org/content/113/4/532.abstract

MCDONALD, C. C., WARD, K., HUANG, Y., WIEBE, D. J., & DELGADO, M. K. (2018). Novel Smartphone-Based Measures of Cell Phone Use While Driving in a Sample of Newly Licensed Adolescent Drivers. *Health Education & Behavior*, *46*(1), 10–14. https://doi.org/10.1177/1090198118788612

MONTGOMERY, J., KUSANO, K. D., HAMPTON, &, GABLER, C., & GABLER, H. C. (2014). *Traffic Injury Prevention Age and Gender Differences in Time to Collision at Braking From the 100-Car Naturalistic Driving Study Age and Gender Differences in Time to Collision at Braking From the 100-Car Naturalistic Driving Study*. https://doi.org/10.1080/15389588.2014.928703

NAUJOKS, F., MAI, C., & NEUKUM, A. (2014). The Effect of Urgency of Take-Over Requests During Highly Automated Driving Under Distraction Conditions. *Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE*, (July), 2099–2106.

NEIL LERNER, JEREMIAH SINGER, DANIEL KELLMAN, & E. T. (2015). In-vehicle noise alters the perceived meaning of auditory signals. *Training and Vehicle Design*, 401–407.

NHTSA. (2018). 2017 Fatal Motor Vehicle Crashes: Overview. Retrieved from https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812603

SANDERS, O. P., SAVIN, D. N., CREATH, R. A., & ROGERS, M. W. (2015). Protective Balance and Startle Responses to Sudden Freefall in Standing Humans. *Neuroscience Letters*, *586*, 8–12. https://doi.org/10.1016/j.neulet.2014.11.034

SIMMONDS, D. J., HALLQUIST, M. N., & LUNA, B. (2017). Protracted development of executive and mnemonic brain systems underlying working memory in adolescence: A longitudinal fMRI study. *NeuroImage*, *157*, 695–704. https://doi.org/10.1016/j.neuroimage.2017.01.016

STEINBERG, L. (2007). Risk Taking in Adolescence: New Perspectives From Brain and Behavioral Science. *Current Directions in Psychological Science*, *16*(2), 55–59. https://doi.org/10.1111/j.1467-8721.2007.00475.x

SUTTER, K., NONNEKES, J., DIBILIO, V., GEURTS, A. C., & WEERDESTEYN, V. (2016). Does the StartReact effect apply to first-trial reactive movements? *PLoS ONE*, *11*(4), 1–11. https://doi.org/10.1371/journal.pone.0153129