Neuromuscular control in critical take-over scenarios: the effect of sex, age, texting, and a startle-based warning

Graci V, Akkem, R, Griffith M, Maheshwari J, Seacrist T, Arbogast, K.

I. INTRODUCTION

Manual take-over actions in highly autonomous may lead drivers to be even more engaged in secondary tasks in the future. This may represent particularly a problem for young drivers, as mobile phone use while driving was specifically found to be a contributor to motor vehicle crashes in teens [1]. In simulated autonomous driving scenarios, sex and age differences in take-over reaction times were found: female adult drivers were faster in reaching for the steering wheel [2] and more accurate [3] in steering than males adult drivers and both female and male teen drivers, during sled-simulated evasive swerving. Teen drivers were also found to be more likely to hold their phone while undergoing take-over actions compared to adult drivers [2]. An Acoustic Startling Pre-stimulus (ASPS, i.e. a loud sound preceding a physical perturbation) warning was previously found to accelerate take-over actions but this was particularly true for adults rather than teens [2]. Although these previous studies were able to characterize reaction times during take-over, neuromuscular strategies used in different age and sex groups remains unexplored. Therefore, the main aim of this study was to examine the effect of Sex, Age, ASPS, and Texting on the neuromuscular control of take-over actions in sled-simulated critical autonomous driving scenarios, such as evasive swerving. A secondary aim of the study was to examine the potential differences of right versus left muscle activations during take-over actions in evasive swerving.

II. METHODS

Fourteen adult (7 males and 7 females, ages 25-37 years old, height 173.3 ± 7.4 cm, weight 68.8 ± 13.8 kg) and 14 teenage (7 male and 7 female, 16.5-17 years old, height 172.3 ± 7.1 cm, weight 65.1 ± 9.4 kg) drivers sat with hands in their lap on a vehicle seat with a 3-point seat belt on an oscillatory sled equipped with a steering wheel and, brake and accelerator pedals. As soon as the oscillatory perturbation (0.75 g, 1 cycle) started, participants were instructed to align a marker on the steering wheel with a marker on a lateral post as fast as they could. Four conditions were examined: with and without an ASPS (105 dB, played 250 ms before sled perturbation for 40 ms), and with and without a secondary task (i.e. phone texting). A catch trial (ASPS only) was used to minimize anticipation. Electromyography sensors were placed bilaterally on the brachioradialis (forearm muscle), the bicep brachii (upper arm), deltoids (shoulder), sternocleidomastoid (SMC, neck), and tibialis anterior (lower leg). EMG data were normalized by maximum voluntary isometric contraction (MVIC) and to the initial muscle activation (before the sled motion). The effects of Sex, Age, ASPS, Side, and Texting on the mean of muscle activation during the first swerve of the oscillatory cycle was examined with Repeated-Measures 5-ways ANOVAs. Tukey's HSD test was used for pairwise comparisons ($p<=0.05$).

III. INITIAL FINDINGS

A significant interaction of ASPS x Age x Texting ($p<0.03$) showed that with the ASPS adult drivers had greater brachioradialis activation without the texting task ($p<0.003$) while the teens showed no differences across conditions ($p=0.9$, Figure 1a). A significant interaction ASPS x Sex ($p=0.03$) showed that overall females showed greater activation of the brachioradialis than males ($p<0.005$), and greater activation with the ASPS than without, but the differences were not statistically significant ($p=0.1$, Figure 1b). An effect of Sex x Side was also found on the brachioradialis ($p>0.03$), showing that females activate their right brachioradialis more than their left ($p<0.001$) while males showed similar activation between sides ($p=0.7$, Figure 1c).

The biceps activation showed a significant interaction Age x Texting: when they are not texting, adults contracted their biceps more than when they were texting ($p<0.0002$) and more than the teens with or without the secondary task ($p<0.0008$, Figure 1d). The deltoid muscles only showed a significant main effect of Side, with greater activation of the right deltoids compared to the left (Right: 0.3 ± 0.3 multiples of MVIC; Left: 0.2 ± 0.5 multiples of MVIC $p<0.0005$). SMC did not show any statistical significance differences ($p>0.1$). Similarly, to the deltoids, the tibialis anterior showed a significant main effect of Side with the right tibialis anterior having a greater activation than the left (Right: 0.1 ± 0.1 multiples of MVIC; Left: 0.04 ± 0.06 multiples of MVIC $p<0.006$).

V. Graci, PhD (graciv@chop.edu), R. Akkem, BSE, School of Biomedical Engineering, Science and Health System, Drexel University, M. Griffith MSE, J. Maheshwari MSE, T. Seacrist MBE, Center for Injury Research and Prevention, Children's Hospital of Philadelphia. K. Arbogast PhD, Perelman School of Medicine, University of Pennsylvania.

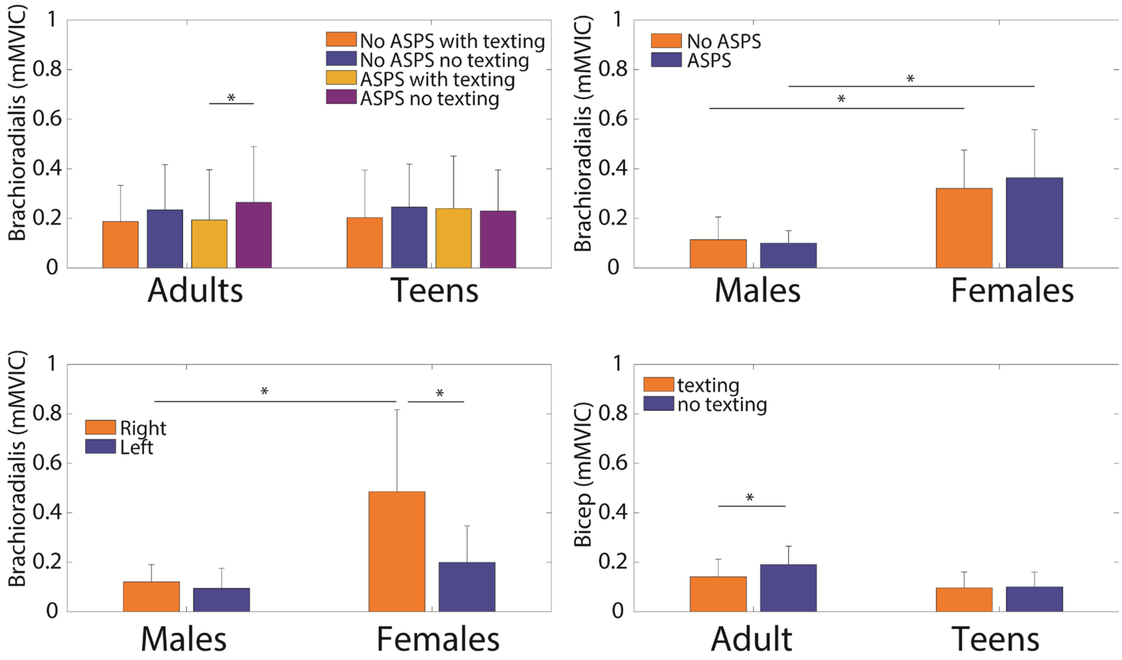

Figure 1. Mean (SD) of averaged EMG over duration the direction of first evasive swerve, shown as multiple of MVIC (mMVIC), for brachioradialis and bicep. P<0.05*.

IV. DISCUSSION

Overall muscle activation found in this study is in line with the kinematic results previously published [2]: previously ASPS was found to accelerate take-over reaction time and adults were found to have shorter take-over reaction times (ASPS (169 ± 55 ms) vs no ASPS 194 ± 46 ms p=0.01[2]), and this was particularly true without the presence of a texting task [2]. Accordingly, our findings showed greater brachioradialis activation in adults when they were not texting with the ASPS present. Females also were found to have shorter take-over reaction time (females 166 ± 58 ms vs. males 199 ± 36 msp=0.009 [2]), and, in line with this finding, in our study female had greater activation of the brachioradialis. Females showed only greater muscle activation in the brachioradialis muscles. As the brachioradialis muscles is responsible for flexing the forearm, it is plausible that female drivers achieved more accurate steering behavior [3] by activating this muscle when moving the steering wheel. Surprisingly, the SCM did not show any differences in activation across conditions. The SCM is a muscle involved in the startle reflex. However overall muscle activation here presented had great variability and that may have masked statistically significant results in muscle activation, although kinematics showed the effect of ASPS [2]. The right deltoid and tibialis muscle showed greater activation than the left ones: the right muscles were likely the most ones involved in bracing against the motion out-of-the-belt caused by the sled perturbation. The right tibialis activation might also have represented the attempt of the subjects to dorsiflex their right ankle to press the brake pedal.

In conclusion, the effect of ASPS, Sex, and Texting on neuromuscular control during critical take-over scenarios was observed mostly in the arm muscles rather than the neck and the lower limb muscles. Teens did not show an influence of the ASPS and Texting on their neuromuscular control, confirming previous findings that found teens not being as fast and accurate as adults in critical steering behavior [3].

V. References

[1] McDonald et al *Health Education & Behavior*, 2019

[2] Griffith et al *Frontier in Bioengineering*, 2023.

[3] Graci et al *Biomedical Sciences Instrumentations*, 2021

VI. ACKNOWLEDGMENTS

The authors would like to acknowledge the Center for Child Injury Prevention Studies at The Children's Hospital of Philadelphia (CHOP) and The Ohio State University (OSU) for sponsoring this study and its Industry Advisory Board (IAB) for their support, valuable input, and advice. The views presented are those of the authors and not necessarily the views of CHOP, OSU, or the IAB members.