Can the acoustic startling pre-stimulus reduce take-over time in critical autonomous driving scenarios?

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Introduction/Objective

In highly autonomous driving scenarios, drivers may take too long to take-over control of the vehicle (Eriksson & Stanton 2017), which may be detrimental during crash avoidance maneuvering. It is critical to identify strategies to accelerate reaction times to minimize crash events and subsequent injury. In previous studies, an acoustic Startling Pre-stimulus (ASPS, i.e. a loud sound preceding the physical perturbation, 105 dB) was found to accelerate motor responses in flexion exercises (e.g. Campell et al 2013).

Therefore in this study we examine if ASPS used as an acoustic warning leads to shorter take-over reaction times in autonomous driving scenarios where vehicle swerving is simulated with lateral sled perturbations.

Methodology

Seven seat-belt restrained adult participants (25-37 y.o.) 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 an oscillatory lateral sled perturbation started (0.75 g). Four conditions were repeated twice and randomized: 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. texting). Human kinematics were collected with an 8-camera 3D motion capture system. The effects of ASPS, Secondary Task, and Repetition on the following outcome measures were examined with Repeated-Measures 3-way ANOVAs: reaction time (RT, i.e. from sled motion onset to hands on wheel), corrective time (CT, i.e. from sled motion onset to marker alignment), and alignment error. Fisher's LSD test was used for post-hoc analysis ($p<=0.05$).

Results

A significant interaction effect between ASPS and Secondary task ($p<0.02$) was found on RT: without a secondary task, RT was shorter with ASPS (Mean ± SD: 413.2 ± 47.5 ms) than without ASPS (Mean ± SD: 462.5 ± 42.7 ms) ($p=0.01$). RT did not differ with ASPS when a secondary task was involved ($p=0.31$).

In the conditions without ASPS, a greater RT variability between subjects was found in the texting trials compared to the non-texting trials (SD: 130.6 ms vs 47.5 ms) while in the conditions with ASPS, the RT variability was similar between texting and non-texting conditions (SD: 47.5 ms vs 42.7 ms).

A significant interaction effect between ASPS and Repetition ($p<0.02$) was found on CT: in the ASPS trials, CT was shorter in repetition 1 (Mean ± SD: 1.0 ± 0.3 s) compared to repetition 2 (Mean ± SD: 1.3 ± 0.4 s) ($p = 0.007$) while no differences between repetitions were found without ASPS ($p=0.76$). Alignment errors were small and did not differ between conditions.

Discussion/Conclusions

ASPS may reduce take over reaction times in autonomous driving scenarios when the drivers are not distracted by a secondary task. Although this effect disappeared when the participants were texting, between-subjects variability decreased with ASPS in the texting trials, suggesting that ASPS may lead to more consistent take-over responses. The increased CT in repetition 2 with ASPS suggests a potential adaptation effect to the startling stimulus. However in real scenarios, drivers will not experience the ASPS as often as in our study.