# The Effects of Engagement in Physical Exercise on Semi-autonomous Takeover Request Perception between Younger and Older Adults

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Adults aged 65 years and older are the fastest-growing age group. An estimated 15 – 20% of the world's population will consist of older adults in 2050, compared to only 5 – 10% in 2019 (United Nations, 2019). Age-related changes in perceptual, cognitive, and physical abilities may make performing instrumental activities of daily living, such as driving, difficult (e.g., Anstey et al., 2005).

Autonomous vehicles have the potential to mitigate mobility concerns for older adults who experience such declines. However, current partial or conditional autonomous vehicles (i.e., SAE Level 2-3 automation) (SAE International, 2018) still require drivers to occasionally resume control. To take over, drivers first need to perceive and process takeover alerts sent by vehicles (in visual, auditory, and/or tactile format), then (re)gain environment/situation awareness, and, finally, execute the action (McDonald et al., 2019).

While completing this complex process could be more challenging for many older adults, research on individual differences reveals that chronological age alone may not be the best predictor of task performance (Czaja, Boot, Charness, & Rogers, 2019). Specifically, factors such as physical (aerobic) exercise may slow down the rate of age-related decline (such as perceptual and processing speed) (Muiños & Ballesteros, 2018). However, there is limited empirical data on whether engagement in physical activity can benefit the performance of older drivers for complex tasks, such as vehicle takeover.

Given the complexity of the takeover process, in this study, we focus on, the first, the perception of takeover requests. Researchers have proposed designing such alerts using a multimodal display approach, i.e., the combination of visual (V), auditory (A), and/or tactile (T) signals. For example, previous studies have found that for younger drivers, tri- and bi-modal signals (VA, VT, AT, and VAT) led to faster response times to takeover requests compared to single modal stimuli (V, A, or T) (e.g., Huang, Steele, Zhang, & Pitts, 2019). However, the extent to which these results hold true for older drivers who regularly perform aerobic exercises is unknown.

This study aimed to measure the effects that engagement in physical exercise, a non-chronological age factor, and takeover request modality have on the perception of alerts in the takeover process during SAE Level 3 autonomous driving. A human-subject experiment was conducted using a medium fidelity driving simulator. Forty-eight participants took part in this study, with 12 participants in each of 4 groups (that is, younger exercise, younger non-exercise, older exercise, and older non-exercise), based on participants' age and their frequency of engagement in aerobic exercises. Takeover requests were presented as V, A, T, VA, VT, AT, and VAT. Participants were asked to drive a Level 3 autonomous vehicle while being presented randomly with the seven types of signals. Participants would step on the brake as soon as they received any alert. Additionally, they were randomly asked to make time-to-collision (TTC) estimates throughout the scenario.

Overall, older adults had longer brake response time to takeover alerts and lower accuracy on the TTC estimation task, compared to younger adults. Aerobic exercise did not result in a significant main effect on brake response time. Both age groups responded faster to multimodal signals compared to single signals. Additionally, for signals that contained a tactile cue, no age-related differences were found.

The benefits of physical exercise may be observed in later takeover stages, such as the post-takeover phase that requires decision making and action execution. Nonetheless, this study generated empirical data on the effects of physical exercise and multimodal signal type on the perception of takeover alerts in the perception and processing phase. Findings may help with framework development, as well as inform the design of autonomous vehicle warning systems.

## ACKNOWLEDGEMENTS

This work was supported, in part, by the National Science Foundation (Grant #: 1755746), as well as the Human Factors and Ergonomics Society Aging Technical Group scholarship.

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