Automated Vehicle Takeover: A Pilot Study on the Effects of Age, Physical exercise, and Takeover Request Modality on Post-Takeover Performance

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Adults aged 65 years and older have become the fastest growing age group (U.S. Census Bureau, 2020). Aging often prompts discussions about how technology can support older adults who may experience perceptual, cognitive, and psychomotor declines, which may cause difficulties in performing daily tasks, such as driving. Vehicle automation represents one technological development that can enable older adults to remain independent in later stages of life. However, current automated vehicles still require human takeover (see a review: McDonald et al., 2019), a process that involves multiple phases and steps, which may be hindered by age-related cognitive and physical challenges. Specifically, drivers need to 1) process takeover requests (TORs) in visual, auditory, and/or tactile sensory modalities (i.e., the signal response phase) and 2) take over control of the vehicle, regain situation awareness, and execute appropriate vehicle maneuvers in a timely manner (i.e., the post-takeover phase).

Aging is a heterogeneous process in that many non-chronological age factors produce vast individual differences (Muiños & Ballesteros, 2018). For example, with respect to physical activity in particular, an older adult who engages regularly in exercise (e.g., running or swimming) may have better cognitive and physical abilities compared to someone of the same age who does not exercise at all. But, findings related to the benefits of non-chronological factors have mostly been demonstrated on simple cognitive tests, such as the Mini-Mental State Exam (Folstein et al., 1975). Thus, it is unknown whether engagement in physical exercise is associated with better performance on more complex tasks, such as automated vehicle takeover.

A recent study investigated the effects of age, physical exercise, and TOR modality on the takeover signal response phase (Huang & Pitts, 2021), and did not found physical exercise to affect response times to TORs. However, older adults had longer braking response times compared to younger adults, but this age difference was mitigated by the effects of multimodal signals (the combination of visual (V), auditory (A), and/or tactile (T) signals), especially for signals that included a tactile component. However, no actual takeover (driving) performance was measured in this previous study.

Therefore, the goal of the current pilot experiment was to extend the previous study (Huang & Pitts, 2021) to examine the impacts of age, physical exercise, and TOR modality on post-takeover performance during SAE Level 3 automated driving. A human-subjects experiment was conducted using a miniSim™ driving simulator. Sixteen participants were equally categorized into four groups based on age (younger vs. older) and physical exercise (active vs. sedentary) (Godin, 2011). Similar to (Huang & Pitts, 2021), seven types of TORs were used (V, A, T, VA, VT, AT, and VAT). Participants rode in an SAE Level 3 automated vehicle in the center of a three-lane highway and took over control of the vehicle after receiving TORs (due to road construction). To avoid collision with the construction, drivers needed to move into the left or right adjacent lane. They also needed to judge the distances between their own vehicle and two fleets of trailing vehicles in both adjacent lanes in order to select the lane with the most available space to move into. Lane-change decision time and post-takeover quality were measured as decision-making time and maximum resulting jerk, respectively.

Preliminary results revealed that older adults had a poorer takeover quality. However, the differences between younger and older adults, in terms of decision time and maximum resulting jerk, were smaller for the physical exercise group compared to the non-exercise group. No effect of TOR modality was found on the post-takeover dependent measures.

Overall, findings highlight the critical need to consider non-chronological age factors in human-automation interaction research. Results may contribute to theories on aging and inform the development of next-generation automated (vehicle) systems.

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