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Before humanity could enjoy the potential benefits of fully autonomous vehicles (e.g., improved mobility options, lower carbon fingerprint, improved road traffic security), a series of intermediate, »conditionally autonomous« driving stages are expected to provide a gradual transition from manual to autonomous driving. The current technology almost completely enables the transition to SAE level 3. In our previous studies we mainly focused on take-overs (TOs) where all the information was communicated to the driver within a single, discrete take-over request (TOR) event. However, ours and related studies showed that a more in-depth approach should be pursued: the TO interaction process should not only consist of a single TOR but should also consider and actively monitor drivers' state and awareness at least until the TO, preferably even longer – monitoring driver's actions even after the control of the vehicle was handed over to the driver until the driving circumstances stabilise. During that time, the vehicle should be able to adapt its behaviour according to driver's abilities. We suggest using a gradual approach with additional warnings also after urgent TORs. Additionally, the results of our previous studies showed that in some cases only lowering the automation level would likely perform better than assuming a complete TO, since some drivers only tend to take-over the lateral or longitudinal coordination of the vehicle instead of both. Partial TOs could therefore enable drivers to takeover only lateral or longitudinal coordination, depending on what they feel capable of, while leaving the other under automated control of the vehicle.

Adaptable Take-Over Concepts: Considering Partial and Gradual Take-Overs

by Timotej Gruden and Grega Jakus

BASIC
(Take-over Request)

AND

Multimodal TOR (directional auditory signal, tactile alert, visual traffic sign)

PTO
(Partial Take-Over)

OR

Besides the multimodal TOR, when a TO is performed by steering, longitudinal coordination remains under automatic control.

MSM
(Minimum Safety Manoeuvre)

TTC <3s

TTC <1s

Besides the multimodal TOR, additional warnings and braking manoeuvres are performed based on drivers' responses (warning, emergency braking, etc.).

PTO + MSM
(Including both PTO and MSM)

PTO + MSM

Our results are based on a driving simulator study where 43 participants took 2 repetitions of each of the 4 trials (TO concepts). In total, 344 TOs were analysed with respect to the 5 dependent variables. When using PTO+MSM, the minimal TTC was on average .434 seconds longer compared to the basic TO concept ($p = .026$) and on average .487 seconds longer compared to the PTO concept ($p = .009$). When using PTO+MSM, the maximal lateral acceleration was on average 0.65 m/s^2 smaller compared to the basic TO concept ($p = .090$), and on average 1.05 m/s^2 smaller compared to the PTO concept ($p = .017$). The maximal lateral acceleration during MSM concept was on average 0.89 m/s^2 smaller compared to the PTO concept ($p = 0.073$). Significantly fewer collisions were observed when using PTO+MSM compared to the basic TO concept, $p < .05$.