

# Human-machine co-operation in car driving for safe lateral control in bends: function delegation and mutual control

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Jean-Michel Hoc, Franck Mars, Isabelle Milleville-Pennel, & Élise Jolly,  
CNRS and University of Nantes,  
IRCCyN, PsyCoTec,  
Nantes, France

## Abstract

This paper aims to identify in-car human-machine cooperation with automation for safety purposes through two experiments carried out on lateral control in bends. The first experiment tested a function delegation mode (FDM) where lateral control is fully automated and longitudinal control remains under driver control. This experiment demonstrated that there were serious difficulties in returning to manual control when skirting around an obstacle, although the device was easy to counter. In addition, spontaneous verbal reports indicated some difficulties in elaborating a mental model of the device and of the function allocation between the driver and the machine. There was also some negative interference between the driver's and the machine's driving styles. The second experiment dealt with the mutual control mode (MCM), where the entire driving task is fully controlled by the driver but the machine can evaluate lateral control and exert mutual control on the driver. It does this either by an auditory and haptic warning (steering wheel vibration) or by a haptic action suggestion (asymmetric oscillation on the steering wheel). The MCM experiment focussed mainly on the driver's recovery from critical situations (deviations provoked by visual occlusions). The warning mode was found to be efficient, whereas the results for the action suggestion mode were not conclusive, both for contextual reasons and because of larger individual differences. In addition, the mutual control mode appeared more efficient in the case of lane departure (toward another lane) than in the case of road departure (stress is much more efficient than mutual control).

## Introduction

While many studies have been devoted to driving support for longitudinal control (e.g., Adaptive Cruise Control, ACC), few studies have dealt with lateral control. A function delegation mode (Active Steering, ASt) has been compared to a kind of ACC on a simulator, as well as to a control situation without assistance (Stanton et al., 2001). A larger decrease in workload has been found with ASt than with ACC, although the former did result in difficulties in returning to manual control for collision avoidance. Indeed, this difficulty is considerable with ACC and with a

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