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RESEARCH ARTICLE

Use of a computational simulation model of drivers' cognition to predict decision making and behaviour while driving

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Abstract
This paper presents a new approach to driving experimentation, based on cognitive simulation of the driver in order to predict human behaviour. The cognitive model COSMODRIVE (i.e. COgnitive Simulation MOdel of the DRIVEr) has been combined with a Vehicle-Environment-Sensors platform (named SiVIC, for Simulateur Vehicule-Infrastructure-Capteur) in order to simulate, explain and predict the driver's behaviour and mental activities. From the simulation of left turn manoeuver, an experiment has been conducted at IFSTTAR — LESCOT, where a hypothesis has been made with the simulation done by COSMODRIVE. The innovative approach is the use of a virtual simulation of a cognitive model to predict human behaviour and then analyse collected data to validate the predicted behaviour. This article describes broadly the COSMODRIVE model and the simulation made in order to define accurate experimental hypotheses. Then, we describe the driving simulator and the experiment itself. Afterwards, data analysis provides us some results allowing us to discuss and conclude about the methodology tested with this experiment.

Introduction: Research context and objectives

During the last few years, our objectives at LESCOT[1] have been to design, develop and implement a cognitive simulation model of the car driver, that is able to virtually

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[1] Laboratory Ergonomics and Cognitive Sciences applied to Transport.

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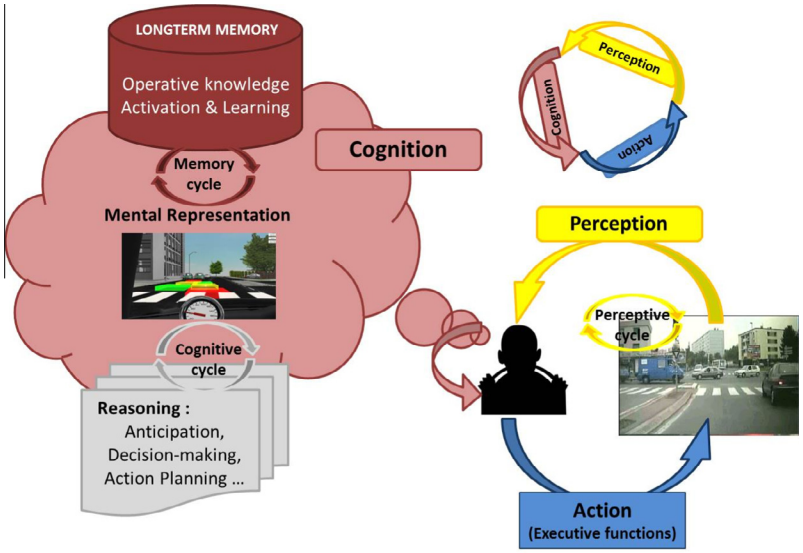

Fig. 1 COSMODRIVE regulation loops.

simulate the human driver's mental activities. This simulation is based on COSMODRIVE[2] (Bellet, Bailly, Mayenobe, & Georgeon, 2007; Bellet & Tattegrain-Veste, 1999), a cognitive model of the driver based on human behaviour observation and analysis, centred around an iterative ''Perception—Decision—Action" regulation process (Fig. 1), and mental representations of traffic situations. COSMODRIVE does not take its root in a ''rule based system" like ACT-R, with procedural and declarative representations. In order to adequately describe dynamic situations and the driving context, COSMODRIVE uses visuospatial representations and cognitive processes that access and utilise data stored in these representations.

These processes are used to simulate the driver's mental activities and behaviour, from the perceptive functions to the operative ones. The cognitive level is centred around *mental representations* (Bellet, Bailly-Asuni, Mayenobe, & Banet, 2009), corresponding to the driver's situation awareness (as defined by Endsley (1995)), which are stored in the working memory. Mental representations are supplied with visual information, coming from the perception module of COSMODRIVE, and are structured around permanent knowledge stored in long term memory and instantiated for a specific situation.

This operative knowledge (Ochanine, 1977) is modelled in COSMODRIVE as *driving schemas* (Bellet & Tattegrain-Veste, 1999). Based on Piaget's (1936), concept of *operative scheme* and Minsky's (1975) *frames theory*, driving schemas separate the environment into two different areas (Fig. 2): driving zones (Z_i), where the driver should progress in order to reach his goal, and perceptive exploration zones (ex_i), where the driver can pick visual information in order to meet conditions to pass from one driving zone to another.

In order to reach the *tactical goal* of an activated driving schema, the driver has to perform actions to move in the driving area and reach a given state at the end of each zone.

[2] COgnitive Simulation MOdel of the DRIVEr.

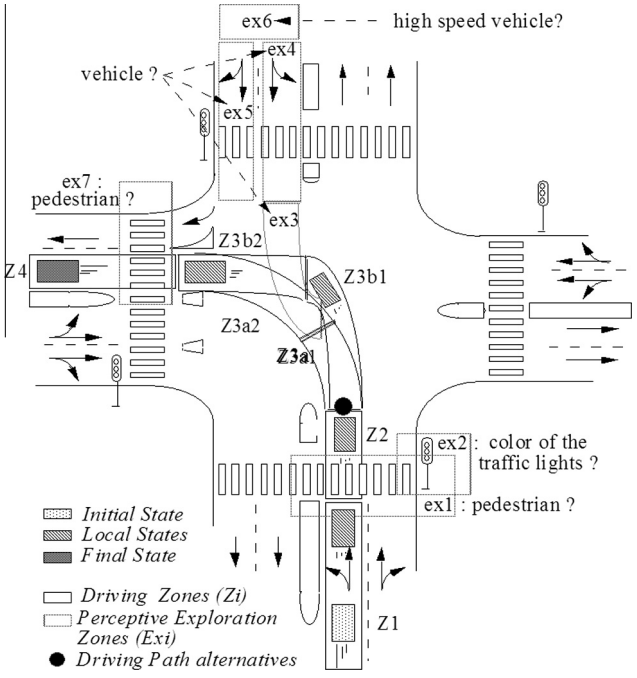

Fig. 2 Driving schema for left turn manoeuvre in COSMODRIVE.

To enter a new driving zone, the driver searches for information in exploration zone(s) that are bound to relevant conditions (e.g. traffic lights colour, presence of pedestrian, etc.) (see Fig. 2). These driving schemas are prototypical situations which can define long driving zones, like in straight road situations. Regulation in a driving zone is the responsibility of the action module, through an automatic control loop.

The action module performs the behaviour determined by the cognitive module due to the activated driving schema and process of anticipation. This action control is based on