Available online at www.sciencedirect.com

ScienceDirect

IFAC Papers Online CONFERENCE PAPER ARCHIVE

IFAC-PapersOnLine 49-32 (2016) 066–071

Simulation and virtual reality-based learning of non-technical skills in driving: critical situations, diagnostic and adaptation

J-M. Burkhardt*, V. Corneloup*, C. Garbay, Y. Bourrier***/**, F. Jambon**, V. Luengo***, A. Job****, Ph. Cabon****, A. Benabbou*****, D. Lourdeaux*******

**IFSTTAR – AME/LPC, 78000 Versailles, France (e-mail: firstname.lastname@ifsttar.fr)*
***LIG – Laboratoire d'Informatique de Grenoble – UMR 5217, UGA-CNRS-Grenoble INP, 38058 Grenoble, France (e-mail: firstname.lastname@imag.fr)*
****LIP6 – Université Pierre et Marie Curie, Sorbonne Universités, 75252 Paris, France (e-mail: firstname.lastname@lip6.fr)*
***** LATI – Université Paris Descartes, 92774 Boulogne Billancourt, France (e-mail: firstname.lastname@parisdescartes.fr)*
****** Heudiasyc – UMR CNRS 7253, Sorbonne Universités, Université de Technologie de Compiègne, 60205 Compiègne, France (e-mail: firstname.lastname@hds.utc.fr)}*

Abstract: Project MacCoy Critical aims to study and to improve training systems using simulation and virtual environments in medical education (obstetrics) and in driving education (novice drivers during the first months of autonomous driving). The paper describes and justifies the main concepts, the approach and the architecture elaborated from a multidisciplinary viewpoint in order to provide more appropriate and flexible Virtual Environments for Learning/Training to support the acquisition of Non-Technical Skills (NTS) by Humans. This is illustrated in the domain of driving education.

Keywords: Virtual Reality, Driving simulation, Human Factors, Educational Aids, Intelligent Tutoring System, Non-Technical Skills.

1. INTRODUCTION

Simulators and Virtual Reality-based Environments are specific interactive systems allowing one or several users to interact with digital simulation of objects and scenes, usually in three dimensions, in a realistic way, by means of a set of interaction technologies covering one or more perceptual modalities amongst vision, touch, kinaesthesia, hearing, etc. These systems allow simulating real environments when one cannot access them, because they are too dangerous or expensive for training use. Moreover, these environments can simulate unexpected scenarios or unusual situations such as accident and failures and some parameters of the situation can be modified (see e.g. Burkhardt, Lourdeaux & Mellet d'Huart, 2006 for a discussion about other potential functions). They provide learners and trainers with a safe and controlled environments, give opportunity for the collection of performance and behavioural data, enable consistent and systematic feedback, and support repetitions. Virtual simulated situations are often restricted, simple and providing trainees with only few variations and a low degree of freedom regarding possible actions and feedbacks within the environment. There is consequently a need for virtual environments that would put trainees into varied ecological situations, inducing knowledge and competencies that would be put into practice in genuine activity situations (Barot, Lourdeaux, Burkhardt & Lenne, 2013). Up to now, Simulators and Virtual Reality-based Environments for learning have mostly targeted the teaching of scientific subjects like physics, astronomy, ecology, etc. for university students and children (see e.g. Mikropoulos & Natsis 2011 for a review), while a less numerous but significant group of systems has targeted adult learning and training. The latter ones are mostly oriented towards the acquisition of "technical" skills, that is the specialized knowledge (e.g. procedures, techniques, regulations) required for carrying out technically the tasks. In contrast, a drastically under-investigated field is related to the learning of Non-Technical Skills (NTS). NTS are "cognitive, social and personal resource skills that complement worker's technical skills, and contribute to safe and efficient task performance" (Flin, O'Connor, & Crichton, 2008).

The objective of this paper is to describe and justify the main concepts, the approach and the architecture elaborated from a multidisciplinary viewpoint in order to provide more appropriate and flexible Virtual Environments for Learning/Training to support the acquisition of Non-Technical Skills (NTS) by Humans. This work has been carried out in the context of project MacCoy Critical (Models for Adaptative feedback enriChment and Orchestration based virtual realitY in Critical situations <http://anrmaccoy.fr/>). This project aims to study and to improve training systems using simulation and virtual environments in two different learning domains in order to favour the genericity of the approach, of the architecture and of the developed components: medical education (obstetrics) and driving education (novice drivers during the first months of driving after the licence). This project focuses on non-technical skills (NTS) in critical situations for these two populations of learners. However, due to length constraints, we concentrate this paper on the driving education domain. The paper is structured as follows: section 2 reports on non-technical skills

10.1016/j.ifacol.2016.12.191

(NTS) and how this Framework may apply in driving education; section 3 present some dimensions of critical situations that could be used to develop scenarii for training/Learning in simulated environments; section 4 briefly describes the proposed approach to support the acquisition of Non-Technical Skills (NTS); section 5 gives a conclusion and perspectives.

2. NON-TECHNICAL SKILLS IN DRIVING EDUCATION

The Non-Technical Skills (NTS) framework has its roots in Crew Resource Management (CRM) techniques developed in aviation and later applied in other risk-prone domains like medicine, chemical industry etc. There are seven core NTS and 25 components (see Table 1). The first and second NTS are cognitive skills, while the third fourth and fifth ones are inter-personal resources and the last two intrapersonal resources (Flin et al., 2008). More recently, Flin and Maran (2015) differentiated features and individual skills of team skills, considering that each of them had an impact on the individual and collective performance in terms of quality and safety). The NTS framework has not been used the domain of road safety and car driving. However, according to many authors, driving skills are hierarchically organized from basic driving skills (e.g. vehicle manoeuvring) to higher order driving skills (e.g. mastery of traffic situations; managing "social and economical pressures") as illustrated in the Goals for Driver's Education (GDE) matrix (Assailly, 2013) that synthesizes the various skills required to cope safely and efficiently with driving situations and the different risk factors. These higher order skills encompass a broad set of skills, most of them belonging to three main classes specifically developed from driving situations: Road's visual exploration skills (Falkmer & Gregersen, 2001; McKnight & McKnight, 2003) road's hazard perception skills (e.g. Curry, Hafetz, Kallan, Winston, & Durbin, 2011; Horswill & McKenna, 2004) and collective driving skills (McKnight & McKnight, 2003; Munduteguy & Ragot-Court, 2011). Such higher order skills share many similarities with skills depicted within the NTS framework. In a recent study (Corneloup & Burkhardt, 2016), novice drivers were interviewed extensively – using a critical-incident-technique (Butterfield, 2005; Flanagan, 1954) – about situations they experienced as "critical" in the sense of being difficult to cope with, dangerous or risky during their first two years of autonomous driving. During the interviews many participants noted as a result of their experience that they changed their behaviour related to skills that appear closely related to NTS. For example, some novices reported significant changes in the way they visually explore the road, in order to anticipate critical situations and to maintain an accurate awareness of the situation. The first few months of driving seem acting as one late chapter of the novice driver's training, enabling them to acquire trough a "learning by doing" process an high enough level of driving NTS to "interact in a safe and efficient way with the road environment" (Deery &Fildes, 1999). The use of simulators and virtual environment to support young novices development of NTS by experiencing critical situations can provide a path to decrease their over-representation in road crashes.

Table 1. Core NTS (Flin, O'Connor, & Crichton, 2008)

Core N-T Skills	Skill components
Situation awareness	Gathering information Recognizing & understanding information Anticipating future states
Decision making	Defining the Problem Identifying options balancing risks, selecting and implementing options Reviewing outcomes
Communication	Giving information clearly and concisely Including context and intent when exchanging information Receive information Identifying and tackling barriers to communication
Team Working	Supporting other Solving conflicts Exchanging information Coordinating activities
Leadership	Using authority & assertiveness Maintaining standards Planning and prioritizing Managing workload and resources
Managing stress	Identifying symptoms of stress Recognizing effects of stress Implementing coping strategies
Managing Fatigue	Identifying symptoms of fatigue Recognizing effects of fatigue Implementing coping strategies

3. DIMENSIONS OF CRITICALITY TO CHARACTERIZE LEARNING SITUATIONS

There is no consensual definition of what is referred to as "critical situations" across the various disciplines and application fields. We identified three main meanings that might provide a theoretical ground towards a clear and operational definition of "critical situations" (CS) in relation to learning. A first meaning refers to situations where "critical incidents" occurred in the sense of the "critical incidents technique". CIT (Flanagan, 1954; Butterfield, Borgen, Amundson, & Maglio, 2005; Cuvelier & Falzon, 2011; Irwin & Poots, 2015) refers to a set of procedures for collecting observed incidents having special significance for the job and activity investigated by the psychologist/ergonomist, and meeting systematically defined criteria like the clarity of the situation "where the purpose or intent of the act seems fairly clear to the observer and where its consequences are sufficiently definite to leave little doubt concerning its effects" (Flanagan, 1954). In this first meaning, critical does not refers to gravity here (although the presence of risks might be part of the situation), but refers to the fact that situation and behaviour observed in this situation are significant and representative of situations that operators have to manage successfully as part of their task/job. In our context, this is related to situations where "critical incidents" relate to the novices being learning in the contexts of their first period of driving after licensing. They are critical because they exceed somehow the capacities of the learner, or because they are novel for the subject in the sense that they