Pedestrian crossing by night time condition: issues from a simulator study in virtual environment

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Outline

• Ifsttar-Lepsis lab
• Driving simulator
• Pedestrian and VR
• Pedestrian & Night condition in VR
• Discussion
Lepsis’ team

Senior Researcher
- Éric Dumont (Head of Lepsis)
- Roland BREMOND
- Viola CAVALLO

Researcher
- Jean-Michel AUBERLET
- Dimitri DAUCHER
- Aurélie DOMMES
- Régis LOBOIS
- Hocine IMINE
- Jean-Philippe Tarel

Engineer
- Isabelle AILLERIE
- Stéphane CARO
- Nguyen-Thong DANG
- Manuel Le PAPE
- Daniel NDIAYE
- Fabrice Vienne
- Énoch ST-JACQUES
- Sio-Song IENG
- Céline Villa

Technician
- Stéphane Aillerie
- Pachak BOUGNALI
- Amélie GRICHI

- And more than 10 non permanent people
LEPSIS’lab

- Laboratory for road Operations, Perception, Simulators and Simulations

LEPSiS conducts applied research at the interface of Computer Science and Cognitive Science:
- Vision (human & artificial)
- Virtual Reality applied to “Driving” Simulators.

LEPSiS runs exceptional experimental facilities:
- Photometry and Visibility Laboratory,
- “Driving” Simulators
IFSTTAR – LEPSIS’s major simulators

3 full-cab car simulators

Moving-base car simulator
With yaw motion

2 pedestrian simulators
For navigating and street crossing

Bicycle simulator
Sensorimotor loop

Dynamic car model
Sound
Non player character
scenario

Motor

Mono/ Stéréo
A simulator

- **Several components**
  - Visual
    - Screen, image (HDR) …
  - Sound
  - Interface
    - Steering wheel,
    - Haptic device
  - Software
    - Non player character, scenario...

- **Configuration**
  - Desktop → motion-based

- **Uses**
  - Validation (objective and subjective process)
• **Different simulators**
  - One simulator for one user
    • Driver, pedestrian, rider...
  - One simulator for one situation
    • Motorway, rural road, urban...

• **Different configuration**
  - Motion-based
  - ...
  - desktop
Different kind of studies

- **To improve the knowledge of human behaviors (driver, pedestrian...)**
  - Impact of distracting objects (smartphone)
  - Perception in poor visibility driving (fog, night)
  - Influence of age, social environment, experience on the behavior (driver, pedestrian)
  - Impact of alcohol, drugs on driving
  - Drowsiness

- **Conception and evaluation**
  - Infrastructure
  - Road devices
  - Ergonomic features
  - New ITS
    - Autonomous car

- **To conduct hazardous studies (in safe environment)**

- **Learning**
Validation ?

Good use ?

User(s) x situation(s)
Evaluating simulators
(through human centered approaches)

High Dynamic Range display
Ranchet et al. 2016, Accident Analysis and Prevention
Shahar et al. 2016, Lighting Research & Technology

Perception-action coupling for street crossing simulation
Maillot et al. 2016, Cognitive Aging Conference
Lobjois & Cavallo 2009, Accident analysis and prevention

Self-speed cues used on a bicycle simulator
Caro & Bernardi 2015, Driving Simulation Conference

Visuo-proprioceptive rendering for motion perception in motorcycle simulation
Lobjois et al. 2016, Transportation Research Part F
Lobjois et al. 2016, Ergonomics

Drivers’ control performance as a function of simulators’ configuration
Rosey & Auberlet 2014, Transportation Research Part F

Subjective and objective evaluation of virtual agents and traffic
Darty et al. 2014, International Conference on Intelligent Virtual Agents
Ketenci et al. 2012, Transportation Research Board

And other ongoing researches...
Pedestrian and Virtual Reality
Pedestrian, walking: a complex system

- Health
  - Obesity
  - Cardiovascular disease
- Environment
  - Noise emissions
  - GHG emissions
- Transportation issues
  - Street crossing
  - Pedestrian falls
- Safety
- Economy
- Urban development
  - Mobility
  - Crowd management
- Mobility
  - ITS (car)
Challenge for pedestrian studies

- “the opportunity for experiential, active learning and the ability to objectively measure behavior in challenging but safe and ecologically-valid environments while maintaining strict experimental control over stimulus delivery and measurement” (Weiss 2004).

- 2015 – Workshop 182
  - Virtual Reality and Efficient Tools for Pedestrian Mobility and Safety
  - P15-6297 – The Use of Simulators for Improving Elderly Pedestrian Safety
    - Viola Cavallo, IFSTTAR – LEPSIS
    - Aurelie Dommes, IFSTTAR – LEPSIS
Pedestrian studies: other examples

- Pedestrian simulators to design and evaluate intelligent transportation systems
- IFSTTAR – LEPSIS
  - Aurélie Dommes
  - Angélique Montuwy
  - Fabrice Vienne
  - Thong Dang
Intelligent transportation systems allowing communications between pedestrians, vehicles and infrastructure

- Since yet several years now, one of the hot R&D subjects for road safety is:
  - V2V (Vehicle-to-Vehicle)
  - and V2I (Vehicle-to-Infrastructure) communications.
- Attention has been put, for example, in detecting pedestrians and predicting the possibility of collisions using vehicle embedded sensors and computer vision techniques.
- Very limited efforts are made on communication mechanisms between pedestrians and vehicles, or between pedestrians and infrastructure to allow for
  - safer itineraries (e.g., to alert pedestrians about the presence of crosswalks, traffic lights and obstacles)
  - safer street-crossing behaviors (e.g., to detect oncoming vehicles before a sufficient amount of time so that reactions for accident avoidance can be taken by pedestrians).
Recent studies at the LEPSiS laboratory were aimed at designing and testing the effectiveness of new intelligent transportation systems allowing communications between pedestrians, vehicles and infrastructure.

Using a simulator is required to allow for a safe and controlled environment, and to test prototypal devices emulating the total and precise communication between infrastructure, vehicles and pedestrians needed for such prototypes, which are not available yet with current technologies but will potentially be possible in a near future with increasing research and developments on connected objects and autonomous vehicles.
The street-crossing simulator

- 10 screens (2.55m x 1.88m) forming a corridor in which the pedestrian can actually walk up to 7 meters
- The images (60 frames per second) are updated interactively by a movement-tracking system that records the participant’s locomotion (sub-millimeter accuracy) and head motion.
- The images represent a two-way street, with vehicles approaching from both sides

This simulator has been used to test an intelligent system allowing pedestrians make safer street-crossing decisions thanks to a smartwatch delivering vibrotactile alerts.
The pedestrian navigation simulator

- The pedestrian navigation simulator allows participants to navigate in a city using a joystick.
- The system includes three 46-inch LCD screens fixed on a U-shaped, shoulder-high metallic frame in front of the participant.
- The system displays 3D visual data representing an urban environment with traffic.

This simulator has been used to test an intelligent navigation system designed to help pedestrians navigate safely in an unknown urban environment thanks to visual, auditory and/or vibrotactile guidance feedbacks.
New situation for pedestrians in VR
Night time conditions !!
Road safety

- **US 2013**
  - 4735 pedestrians were killed (~66,000 injured)
  - Dark (72%), daylight (25%), dawn (2%), dusk (2%)

- **France 2014**
  - 543 pedestrians were killed (~11,533 injured)
  - Day (72%), dark (28%)
    - Mortality rate is higher in dark conditions

- Pedestrian Safety in night condition is a major stake

- Virtual environment is a suitable tool?
High Dynamic Range (HDR) Displays

- The luminance range of usual display devices is limited with respect to the actual visual experience
- Three main problems: limited contrast, poor black, rough sensitivity (8-bit images), no glare.
- Seetzen et al. (2004) designed a High Dynamic Range device, which was further available on the market
- What’s new? Near scotopic black values, high contrasts (1000 times better), 16-bit images, limited glare.

→ HDR display may contribute to virtual reality experiments in nighttime environments.

HDR Displays in transportation studies

Several studies have been conducted at the IFSTTAR institute in recent years, focusing on nighttime transportation issues:

- Behavioral study: testing an innovative LED-based road studs system – vehicle control improvement in curves at night (INROADS European Project, published in Lighting Research and Technology). [driver]
- Behavioral study: assessing the driver’s behavior in glary conditions at night with a cataract pathology (Brémond, Dommes & Engel, unpublished). [driver]
- Virtual Reality study: assessing the relevance of HDR displays with respect to the time-to-collision estimate in nighttime environments (Villa, Brémond, Girard & Ranchet, unpublished). [driver, pedestrian]
Study

• Impact of night conditions on pedestrians’ decision to cross the street

• Road safety challenge

• To define a pertinent apparatus
Apparatus

Experimental setup

The instrumentation used
- HDR screen
- PC

Instruments for the reproduction of sounds and user command
Experimental setup

- In relation to the height of the point observed (1.75 meters), the height of each participant is modified through the use of a variable height support
- All participants are positioned at a predetermined distance from the screen

- Urban one-way street

- The participant is invited to look in a precise point on the screen in relationship at the coordinates of appearance of the vehicles
Day

Dusk

Night
Experiment

- **31 participants between 25 and 45 year old (31 +/- 6)**
  - 18 men and 13 women

**Independent variable**
- Illuminating conditions
  - Day vs dusk vs night
- Time gap
  - 1s to 6 sec (step 1)
- Vehicle speed
  - Slow (40km/h) et fast (60 km/h)

**Dependent variables**
- Decision rate
- Unsafe decision rate
- Initiation time
- Safety margin

**Protocol**
- Walking speed measures
- Familiarization phase
  - 18 trials
- Experimental phase
  - 16 time gaps * 2 speeds * 3 illuminating conditions
  - 96 trials per subject
Relevance our simulator

- Comparison with previous studies
- With a different simulator
- Only for day conditions
Inrets one-way street-crossing simulator

Simulation device adapted from our driving simulator Sim²

- Real portion of road (4.2 m) with markings on the floor
- Computer-generated images projected on 3 screens, displaying traffic from one side
- Movement tracking system (cable attached to the waist)
Studies using the one-way street-crossing simulator

Studies on street-crossing behaviour

- Scenario: 3 vehicles approaching at constant speed
- Gap acceptance paradigm: judgment whether crossing between the 2\textsuperscript{nd} and 3\textsuperscript{rd} vehicle was possible

Lobjois & Cavallo, AAP, 2007, 2009
Lobjois et al., AAP, 2012
Studies using the one-way street-crossing simulator

• **Experimental variables:**
  – Age of pedestrians (20-30; 60-70; 70-80)
  – Speed of approaching cars (40, 50, 60 km/h)
  – Available time gap (1 – 8 s)
  – Decision making with vs. without time pressure
  – Task: judgment vs. actual crossing

• **Behavioural indicators**
  – Median accepted time gap
  – Crossing initiation time
  – Safety margin (SM)
  – Unsafe crossing decisions (SM < 1.5 s)
  – Missed opportunities
Results:
Time Gap Trends
Results:
Unsafe decision trends
Conclusion

- Our apparatus (and our study)
  - First validation (trends)
    - Day conditions

- “good” results

- Other illuminating conditions can be interpreted
Results of this study

• Impact of illumination conditions on street-crossings decisions
  - Decision (illumination condition, speed, time gap)
  - Unsafe decision (illumination condition, speed, time gap)

• Paper: 17-05175
  - IMPACT OF DAY, DUSK, AND NIGHT CONDITIONS ON PEDESTRIANS’ DECISION TO CROSS THE STREET
  - Session: 806, Pedestrian Safety and Behavior
  - Session Location: Hall E / Convention Center
  - Session Time: Wednesday, Jan 11, 2017 8:00AM 9:45AM
  - Posterboard Location Code: H323
Discussion
SWOT of driving simulators

- **Strength**
  - “low cost”
  - Safe env.

- **Opportunities**
  - Social env.
  - Popular (cost)

- **Weakness**
  - # real world
  - Social env.
  - protocol

- **Threats**
  - standards
  - validation
Thank you for attention.

Questions?

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• **Identification of the objective**
  - What kind of VR tools

• **Standardization**
  - Devices and software
  - Protocols (shared by the community)

• **Validation**
  - Tools
    - Identification of the needed skills
  - Results
    - Assessment of the learned skills

• **Transfer to the real world**
  - Sharing experiences

• **Cross-comparison**
  - Pedestrian
  - Driver

• **Impact of light**
  - Car
  - Public light
  - Glare effect
  - Detection