Effectiveness of Forward Collision Warnings for Different Driver Attention States

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Introduction

- Rear-end crashes: second largest collision type
- One main reason for rear-end collisions is driver inattentiveness

n = 310,806 accidents with casualties


collision with ...

- parked vehicle
- vehicle moving ahead or waiting
- vehicle moving laterally in same direction
- oncoming vehicle
- vehicle which turns into or crosses a road
- pedestrian
- fixed Object or vehicle leaving carriageway
- Accident of another kind (unknown, not fixed object, animal ...)

Sources: StBA, GIDAS, Year 2009
Collision Warning Systems

- **Aim of collision warning systems**: help the driver to prevent or mitigate collisions
- **Challenge**: to convey the same urgency and to obtain a high effectiveness for attentive and inattentive driver state at the same time.
- **Approach**: Adaptive Collision Warning System
  - **Target**: Benefit and acceptance increase of common collision warning systems.

![Diagram](image)

- Data
- Attentiveness
- Criticality
- Driver state
- Assumption for driver reaction time

Warning System

- Warning 1 for attentive drivers
- Warning 2 for inattentive drivers

Proceedings for HMI Evaluation

Requirements

→ A warning should
  ● attract the driver’s attention to the dangerous situation
  ● generate a collision mitigating driver reaction
  ● possess a minimum of intensity, multimodality and appropriate warning point in time
  ● be compatible to the critical event
  ● be not too complex and be consistent with other indication signals
  ● be acceptable by the driver

Procedure

→ The investigation of the driver behavior with selected HMIs was carried out in two stages in a fixed based simulator.

Stage 1
● Acoustical Warning

Stage 2
● Visual Warning
Methodology

- 58 participants (32 first stage, 26 second stage) completed two drives
  - First drive: inattentive driver state
  - Second drive: attentive driver state

Secondary task: Navigation Instruction

Design of the most frequent rear-end crash scenario (Wiacek et.al. (1999))
Stage 1: Acoustical Warning

→ Target of Stage 1: Determination of an acoustical HMI, which provokes short reaction times for attentive and inattentive driver state.

→ Selected acoustical Signals for the evaluation:
  - Earcon: Alarm 1, Alarm 2
  - Auditory Icon: tire screeching
  - Hybricon: Combination of earcon and auditory icon (tire screeching)
  - Speech Message: “Bremsen”, which means “to brake” in German
Results: Inattentive driver state

- Indicative reduction of reaction times by the Speech Message ($p = 0.130 > 0.05$).
- An analysis was performed with the best two tones (Speech Message & Alarm2) and the control group revealed an indicative reaction time reduction ($p = 0.093 > 0.05$).
- An acoustical warning with a clear message such as the speech message is necessary to guide the drivers attentiveness to the imminent danger.

*) no acoustical signal, statical warning triangle
Results: Attentive driver state

- Experiment set-up affect the reaction of the drivers in the second drive
- No significant reduction of the reaction times in attentive driver state was observed.

*) no acoustical signal, statical warning triangle
Stage 2: Visual Warning

Target of Stage 2: Determination of a visual HMI, which provokes short reaction times for attentive and inattentive driver state.

Visual warning display in HUD. Selected visual signals for the evaluation:
- Warning triangle
- Brake bar
- Brake light
- Collision notification
Results: Inattentive driver state

- No additional reaction time reduction in an inattentive driver state could be demonstrated for the examined visual warnings ($p > 0.05$).
- The acoustical warning is the main component of a multimodal HMI for inattentive driver.
- An intuitive and simple visual warning could serve to affirm the audible warning.

*) speech message, no visual warning

Chassis Systems Control

Results: Attentive driver state

- Significant reaction time reduction by the brake bar compared to the collision notification ($p = 0.005 < 0.05$).

- A comparison between brake bar and control group revealed statistical significance ($p = 0.017 < 0.05$).

- A simple, intuitive visual signals with a clear message can reduce the reaction time of attentive drivers.

*) no acoustical warning, no visual warning
Summary

- An acoustical warning with clear message reduces the reaction time of inattentive drivers indicatively.
- A simple, intuitive visual warning compatible with the critical event and with a clear message reduces the response times of attentive drivers significantly.

- An adaptation of the warning intensity and modalities to the driver’s attention can be useful to increase the benefit and the customer acceptance of collision warning systems.