Abstract
This study investigates the effect of the follower and leader vehicles’ speed on time headway variation during deceleration in a car-following task. Significant results were found in deceleration onset; headway varies significantly when absolute and relative follower speed are high. These results suggest possible application in the tuning of in-vehicle advanced system for longitudinal safety control.

Keywords
Time headway, driver safety, speed headway keeping

ACM Classification Keywords
H.1.2 User/Machine Systems;

Introduction
In the last 15 years a lot of expectations have been put in the development of various Advanced Driver Assistance Systems (ADAS), reputed as sound solutions for safer mobility [1]. Among these, Speed Headway Keeping (SHK) systems represent a promising approach to reduce one of the main risk factors contributing to road accidents. The lack of proper inter-vehicular distance is indeed considered responsible for a high share of injuries and fatalities in European roads, as rear-end accidents, mainly due to safe headway
violations, represent the 15% of all road accidents, and the 3.5% of all fatal accidents [2].

The impact of SHK systems on road safety has been recently reappraised, as a result of the development of newer devices and prototypes which, beyond the display of a mere warning, can inhibit acceleration and provide tactile feedback to prevent rear-end collisions. For example, Marchau et al. [3] argued that SHK systems may have an impact on road safety even superior - for a comparison - to Intelligent Speed Adaptation systems in avoiding accidents on speed stretches higher than 100 km/h, estimating an absolute 14% fatal crashes reduction and a 57% other accidents reduction, compared to a 10% and a 18% estimated for ISA (Intelligent Speed Adaptation) systems.

**Safe headway maintenance**

Most of the road codes in European Countries recommend a safe headway of 2 seconds minimum even if, according to Vogel [4], there is no complete agreement about safety time margins to be kept when following a vehicle. For example, Evans [5] pointed out that no headway less than 2 s should be considered as safe enough to prevent from possible conflicts with vehicles ahead. Aside from safety recommendations, different studies showed that drivers do not keep safe (higher than 2 s) headway distances; when driving in urban areas, drivers normally choose to follow a preceding vehicle within a 2 seconds region headway [6]. On motorways, it has been found that the most preferred headway is around the region of 2 seconds, and that about 28% of drivers actually choose a headway distance inferior to 2 seconds, and about 13% of drivers circulate with a headway distance less than 1 second [7].

**Perceptual limitations in headway control: a driving experiment**

While behavioral studies in the field have mainly focused on drivers’ risk expositions, in a previous study we have focused our attention on perceptual limitations in people’s ability in actual usage of visual information for effective headway maintenance [8].

This study was conducted inside a experiment carried out on a driving simulator equipped with traditional car controls (pedals, steering wheel). All data coming from the interaction between drivers and driving controls were recorded by the simulation software. The experiment involved 18 drivers in car-following tasks. Subjects were asked to drive for 13 min into two straight roads (A and B – see table 1) maintaining a constant speed of, respectively, 50 and 130 km/h without a preceding vehicle; otherwise, adapting their speed according to the speed of the preceding vehicle in order to avoid impacts.

During the car-following tasks, subjects encountered two vehicles with different sizes: a small city car and a travel-bus. The speed of the leaders in the virtual environment was established as follows.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Absolute speed Follower [km/h]</th>
<th>Absolute speed Leader [km/h]</th>
<th>Leader size</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>130</td>
<td>80</td>
<td>CAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td>BUS</td>
</tr>
<tr>
<td>B</td>
<td>50</td>
<td>0</td>
<td>CAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>20</td>
<td>BUS</td>
</tr>
</tbody>
</table>

**table 1. Car following tasks**
Between the subsequent car-following tasks, the driving scenario was represented by a straight road without obstacles that led followers to achieve the suggested absolute speed (130 and 50 km/h). Thus, each car-following task was completed starting from the same follower’s speed conditions. The response given by the tested subjects on accelerator, brake pedal’s position and vehicle speed were measured. The drivers’ behavior was computed using Headway, a measure of longitudinal behavior:

\[ (H)eadway = \frac{D_t}{V_t} \quad [s] \]

where \( V_t \) is the instantaneous follower speed and \( D_t \) the distance between leader and follower. The role of the relative rate of change of optical expansion of the vehicle ahead was investigated (\( \tau \) or tau, see [8]) aiming at describing followers deceleration strategies.

**Experiment results**

According to the achieved results, drivers appear to use the \( \tau \) (\( \tau \)) as a primary element to determine the “action point”, since the double of \( \tau \) specifies the amount of time needed to null the actual speed difference. Coherently, when approaching a moving obstacle during car-following, drivers waited until \( \tau \) reached a certain value, corresponding to a preferred amount of deceleration needed not to exceed the preferred margin at the end of the decelerating maneuver. Since a first order derivative of the optical expansion of the obstacle is used in \( \tau \) computation, the drivers’ behavior resulted as affected by relative speed and consequently headway at decelerations onsets were lower when relative speed was the greatest (\( p < 0.001 \)).

![Figure 1](image1.png)

**Figure 1.** Headway at decelerations onsets on relative traveling speeds (in seconds).

![Figure 2](image2.png)

**Figure 2.** Headway at decelerations onsets on absolute traveling speeds (in seconds).

While this finding is coherent with previous research that showed limitations in actual usage of visual information in stopping tasks (e.g. [9]), it still remains...
unclear if general effects of absolute speed on headway at deceleration onsets ($p < 0.005$) and deceleration endings ($p < 0.001$) are due to systematic limitations of the optical variables which may be used in headway estimation (e.g. actual distance from vehicle ahead, and Global Optic Flow Rate which specifies absolute traveling speed), or are alternatively due to the fact that drivers discard headway information and merely rely on actual and future distance estimations. Obstacle size did not affect subjects’ behavior, which may be due to drivers’ compensation with previous knowledge of their dimensions.

**Conclusions**

Results depicted in figure 1 and figure 2 show that, in a car-following task, drivers at deceleration onset maintain a significantly shorter headway distance when:

1. absolute follower speed is high;
2. relative speed (the difference between leader and follower speed) is high.

Possible implications for Speed Headway Keeping system design might concern, for instance, the tailoring of SHK intervention strategies for rear-end collision prevention (e.g. acceleration inhibition) as a function of the deceleration onset situation. SHK interventions could be tuned according to vehicle status (high absolute follower speed or high relative speed) and deceleration phase (onset) since it was found that conditions (1) and (2) generate a decrease of time headway between vehicles. Coherently, SHK systems should provide a higher intervention on the accelerator pedal only when a less safe time headway is expected to let the follower enough time to adjust the vehicle speed and reach a safe condition.

**Citations**


