Speed-related auditory feedback from an electric vehicle on the braking behavior in a 3D-driving simulator

Perceptual and Motor Processes in Driving Assessment and Design II / AHFE 2012

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Speed choice and driving safety

Drivers’ choice of speed: predictor of crash risk

- Roadside observation (Wasielewski, 1984)
- Self-report (French et al., 1993)
- Simulation (Horswill & McKenna, 1999)
Speed choice and electric vehicles

Optimistic projections:

“Because drivers may try to conserve battery power, they would not push their car and may tend to stay well within the speed limit”

“The unintended benefit could be one of improved safety, bringing down driving speeds”

⚠️ What about speed perception when driving???
Speed choice and speed perception

Drivers’ choice of speed depends on:

- Personality traits (Delhomme et al., 2009)
- Perceived actual speed (Horswill & McKenna, 1999)

Visual cues

Auditory cues

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Speed choice and speed perception

Speed perception arising from multisensory integration

Internal car noise crucial for speed visual judgements (Horswill & Plooy, 2008a)

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Speed choice and speed perception

(Horswill & Plooy, 2008a)

The reduction in noise led to participants judging speeds to be significantly slower.
Remaining questions

Sound relevance for speed perception in electric cars?

Direct transfer from speed perception to driving behavior?

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Purpose of the study

Audiovisual integration on driving behavior

- Speed-related auditory feedback from an electric car in a 3D-driving simulator
- Speed-related effects investigated on braking

Main hypotheses

- Lower auditory gain ⇝ speed understimation ⇝ delayed and abrupt braking
- Enhanced influence when speed-related visual cues are poor
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Sketch trial and collected data

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## Context & Issues

- **Visual Scene 1** (poor optic flow)
  - Speed: 90 km/h

- **Visual Scene 2** (Rich optic flow)
  - Speed: 90 km/h

<table>
<thead>
<tr>
<th>Stopping Distance 1</th>
<th>Stopping Distance 2</th>
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<tbody>
<tr>
<td><strong>Visual Scene 1</strong></td>
<td><strong>Visual Scene 2</strong></td>
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<tr>
<th>Auditory Gain</th>
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<tr>
<td>Referred to visual kinematics:</td>
</tr>
<tr>
<td>+20%</td>
</tr>
<tr>
<td>+10%</td>
</tr>
<tr>
<td>-10%</td>
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<tr>
<td>-20%</td>
</tr>
</tbody>
</table>

- X 3 repetitions

### Exp Plan: 2 Vis_S x 2 Stp_D x 5 Audit_G x 3 r

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The shorter the stopping distance, the further the final car position (i.e., closer to the light as drivers stopped before the target on average).

Neither main effects of the visual scene and the auditory gain nor interactions between these factors.

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Braking time

- The shorter the stopping distance, the shorter the braking time
- Greater variability for the longer stopping distance
- Neither main effects of the visual scene and the auditory gain nor interactions between these factors

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Reaction time

- The shorter the stopping distance, the shorter the reaction time to brake.

- Greater RT variability for the longer stopping distance.

- Neither main effects of the visual scene and the auditory gain nor interactions between these factors.

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Deceleration peak

The shorter the stopping distance, the higher the deceleration peak.

Greater variability for the longer stopping distance.

Neither main effects of the visual scene and the auditory gain nor interactions between these factors.

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Brake pedal’s relative time-to-peak velocity (!)

The shorter the stopping distance, the shorter the pedal’s relative time-to-peak velocity

Greater variability for the longer stopping distance

Neither main effects of the visual scene and the auditory gain nor interactions between these factors

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No significant effect of sound manipulation... Why?

H1 Speed-related visual cues are informative enough

- Both "rich" and "poor" optic flow conditions convey relevant information about speed and are not sufficiently discriminant
- Extremely poor optic flow (e.g., fog or night) needed in 3D-space for the sound to become relevant (Horswill et Plooy, 2008b; Pretto, Bresciani, & Bülthoff, 2010)?
No significant effect of sound manipulation... Why?

**H2** The tested range of sound levels is too small

**Auditory Gain**

Referred to visual kinematiks:
+20% = 70 dB at 108 km.h⁻¹
+10% = 69 dB at 99 km.h⁻¹
68 dB at 90 km.h⁻¹
-10% = 67 dB at 81 km.h⁻¹
-20% = 66.2 dB at 72 km.h⁻¹

Less than 4 dB
vs 5 dB in Horswill & Plooy (2008a)

Larger intensity range (> 4 dB) for the sound to become discriminant for speed perception in electric cars?

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No significant effect of sound manipulation... Why?

**H3** The speed-related sound from an electric car becomes relevant at higher speeds.

**Auditory Gain**

Referred to visual kinematiks:

- +20% = 70 db at 108 km.h⁻¹
- +10% = 69 db at 99 km.h⁻¹
- 68 db at 90 km.h⁻¹
- -10% = 67 db at 81 km.h⁻¹
- -20% = 66.2 db at 72 km.h⁻¹

may auditory meaningful cues for speed perception be speed- and frequency-dependent?

Different Sound Frequency Spectra between combustion and electric cars (Kim et al., 2012)

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No significant effect of sound manipulation... Why?

**H4** The speed-related sound from an electric car becomes informative *when it varies*

**Auditory Gain**

Referred to visual kinematiks:

- $+20\% = 70\text{ db at } 108\text{ km.h}^{-1}$
- $+10\% = 69\text{ db at } 99\text{ km.h}^{-1}$
- $68\text{ db at } 90\text{ km.h}^{-1}$
- $-10\% = 67\text{ db at } 81\text{ km.h}^{-1}$
- $-20\% = 66.2\text{ db at } 72\text{ km.h}^{-1}$

$\times 3$ repetitions

- The constant speed before braking may decrease the sound relevance for speed perception

- Refresh inputs for multisensory integration (Bringoux et al., 2009)

- Auditory cues $\Rightarrow$ speed perception or change in speed perception?
No significant effect of sound manipulation... Why?

**H5 No transfer from speed perception to driving control**

- Mismatch between perceptual states and sensorimotor control (e.g., Bringoux et al., 2012)

- Nine on the 12 participants explicitly declared having noticed a manipulation of speed across trials

- Speed perception vs speed control?

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Conclusion: speed-related sound and electric car issues

Ongoing and future studies on:
- Audio-visual interactions
- Sound structure
- Sound dynamics

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Thank you for your attention!

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Pretto, Bresciani, & Bülthoff (2010)
Reduced luminance = increases perceived speed = decreases driving speed
Speed was underestimated with distance-independent contrast reduction but overestimated with distance-dependent contrast reduction
Participants increased speed with distance-independent contrast reduction but decreased speed with distance-dependent contrast reduction.

Development of auditory concept of car speed is gradual and initially favors sound level explanation (Gatehouse & Frankie, 1980).

Judged speeds of collision when braking from different speeds are always underestimated (Svenson, Eriksson, et Gonzalez, 2012).
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http://www.realite-virtuelle.univmed.fr/
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Enjeux et contexte  Rappels Protocoleires  Résultats  What’s next ?

SC latency

scene riche ; distance d’arrêt 80m

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