Quiet Cars@BMW.
Challenges for Vehicle Safety and Acoustics.

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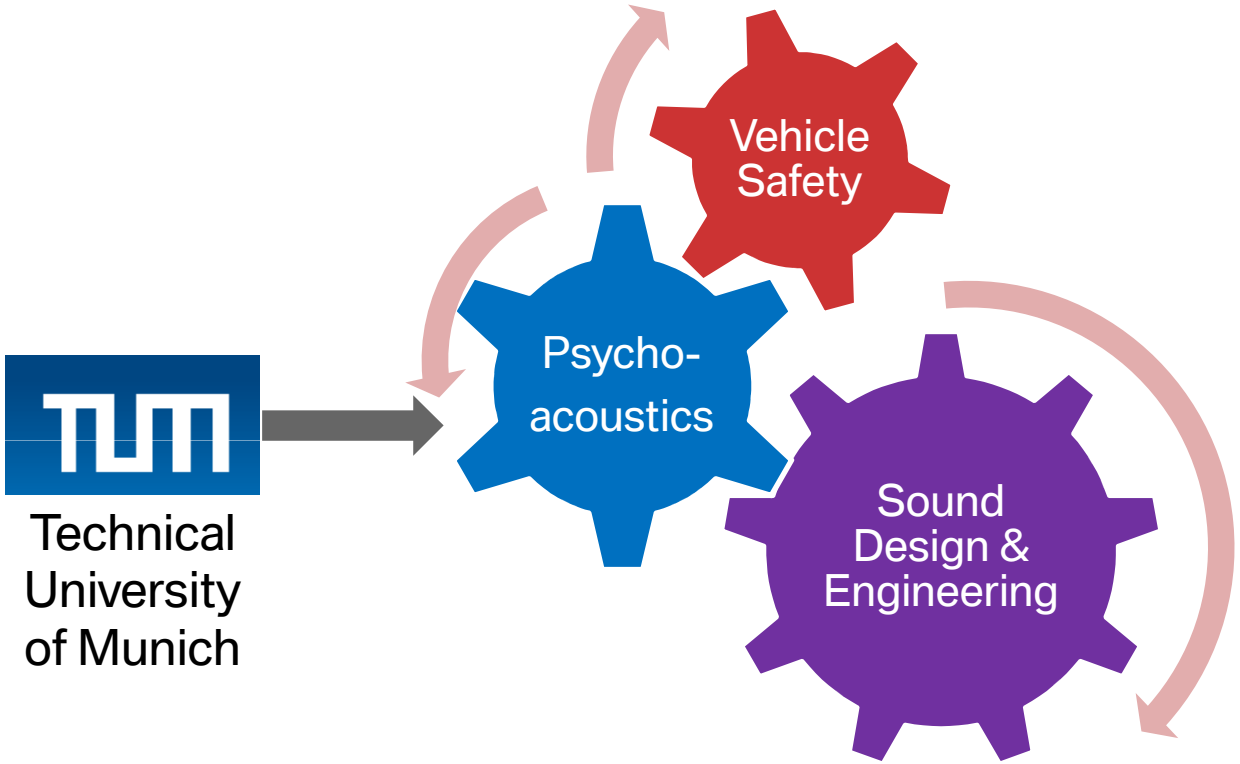
BMW Group

Introduction.
Basic Attitudes and Strategic Statements.

- Corporate values of BMW are based on sustainability and social responsibility
- Need for specific safety measures for EVs and HEVs has been acknowledged for a long time
- Research into evaluation methods has been performed in alliance with Daimler, Porsche and the Technical University of Munich
- Acoustical warning devices are currently being developed for all EVs and HEVs at BMW
- BMW has a supportive attitude towards research and development of non-acoustical approaches as well
- Note: not only pedestrians but also drivers will benefit from warning function (stress reduction)

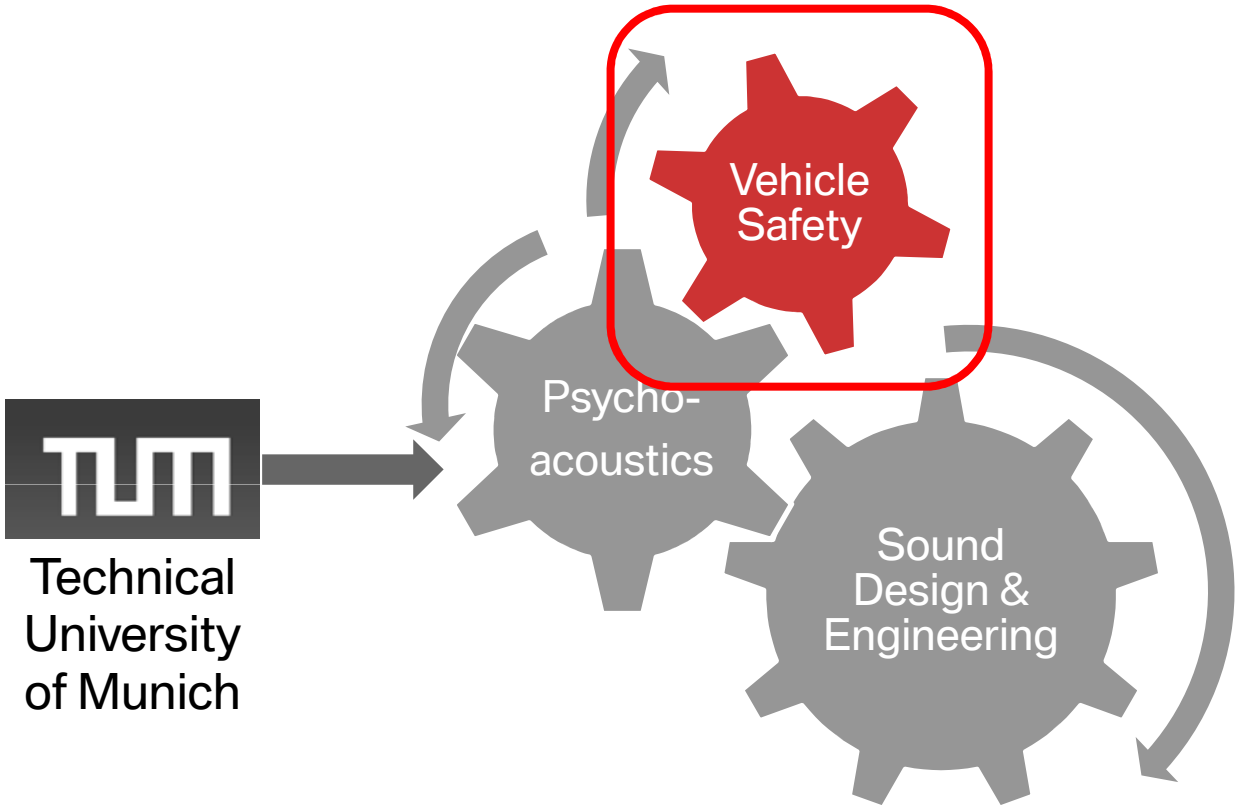
Introduction.
BMW Approach and Responsibilities.



Interdisciplinary team of safety specialists, acoustical engineers, sounddesigners & psychologists

BBSB
Bayerischer Blinden- und Sehbehindertenbund e.V.
(Bavarian Assoc. of Blind & Visually Impaired People)

Introduction.
BMW Approach and Responsibilities.



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Vehicle Safety.
Risk Assessment.

Exploration of safety-relevant traffic scenarios

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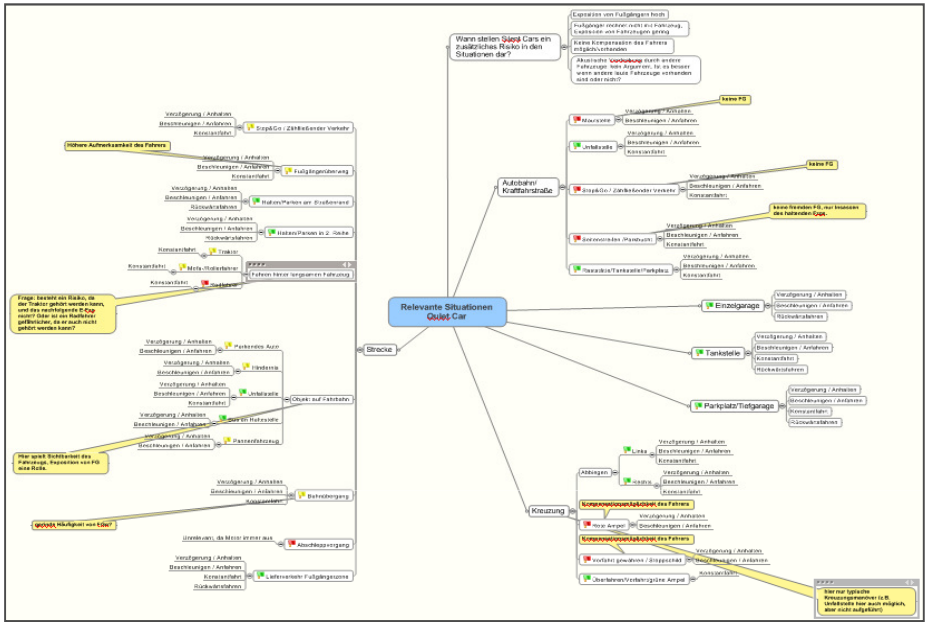
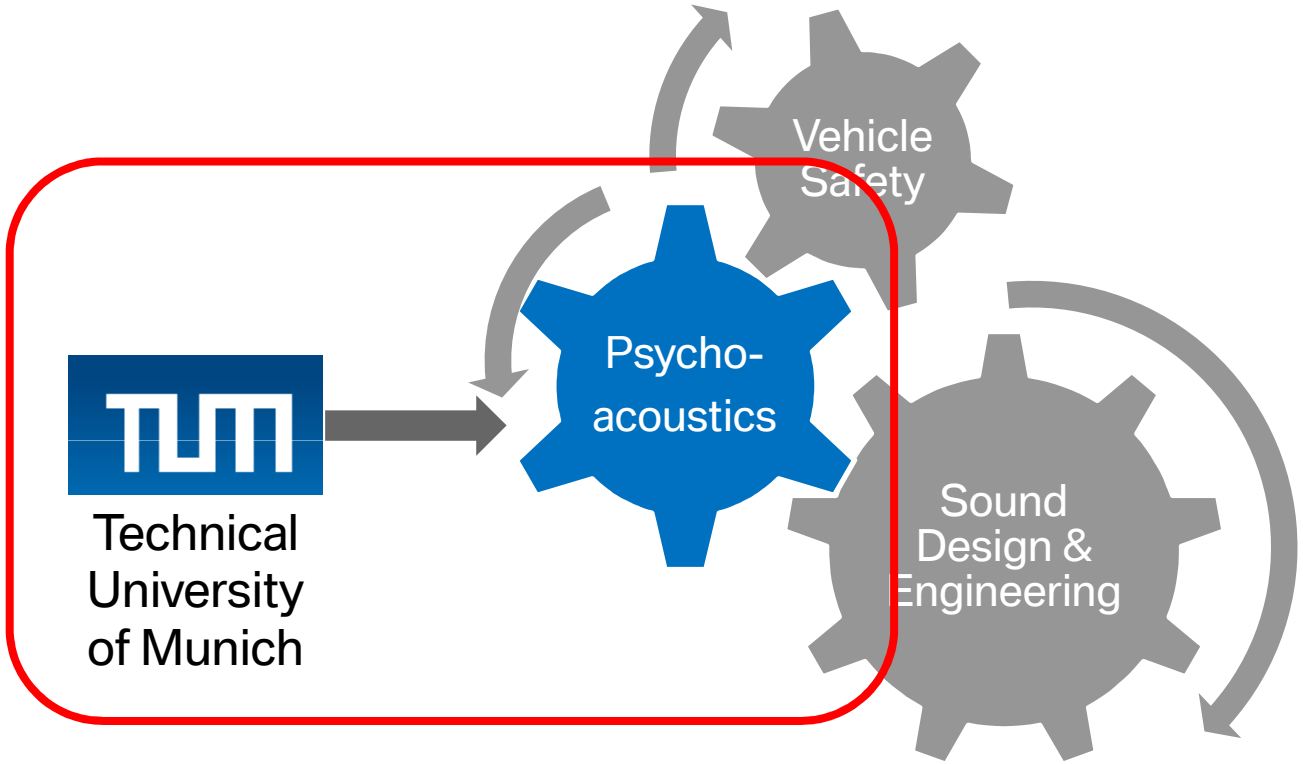
Definition and priorization of situations



Top Critical Situations at v = 0-19 mph (0-30 km/h)	Most Critical Driving State	Risk Level
stop & go, turning, green traffic light without acoustic signal	driving at constant speed	**6**
public car parks (buildings)	accelerating (and driving at constant speed)	**6**
starting into the traffic after a stop on the lane	accelerating	**4**
driving behind very slow and big vehicles (optically and acoustically covered)	driving at constant speed	**4**
private car park / close to street	accelerating	**3**
accident situation	driving at constant speed	**3**
public car parks (open area)	driving at constant speed	**2**
driving behind slow but small vehicles (visible, but acoustically covered)	driving at constant speed	**2**
obstacle on lane (vehicle, bus, ...)	accelerating	**2**

BMW Approach and Responsibilities.
Psychoacoustics.



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Psychoacoustics.
Requirements for Exerior Noises of EVs.

Requirements	Description
Perceptibility	Vehicle noise can be **detected** in background noise in a safe distance
Pleasantness	Avoids **annoyance** at least and creates **esthetic value** at best
Identifiability	Noise is **recognized** as a vehicle
Dynamic Information	Vehicle **speed** and acceleration/slowing is being conveyed
Localisation	**Position** of vehicle can be perceived easily

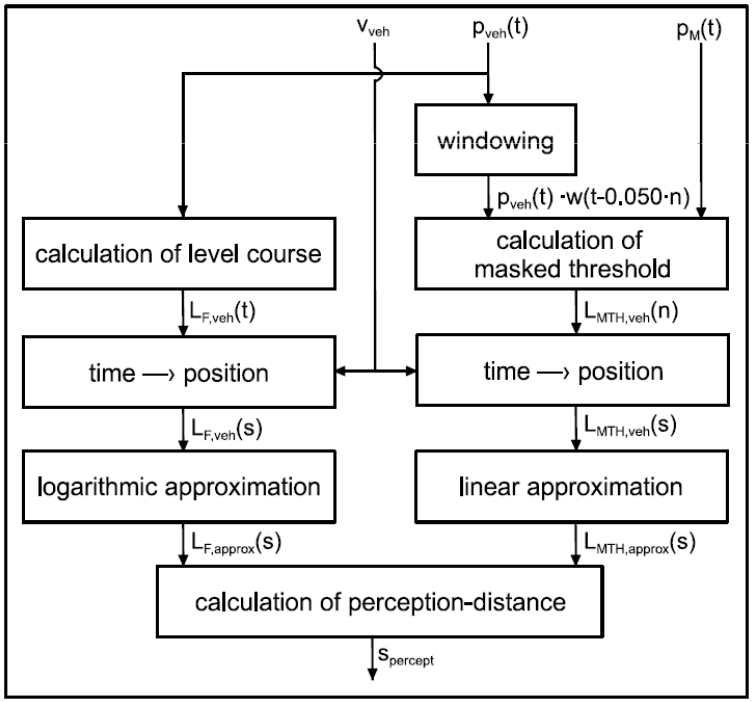
Psychoacoustics.

Assessment of Perceptibility (Kerber, 2008).
Calculation of Perception Distances.

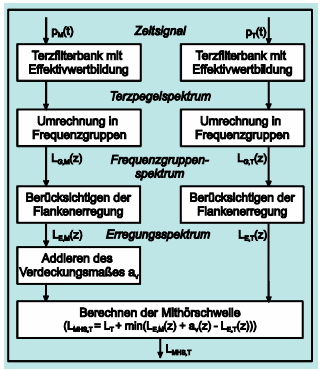
Vehicle Speed

Time varying sound-pressure of masker

Time varying sound-pressure of vehicle



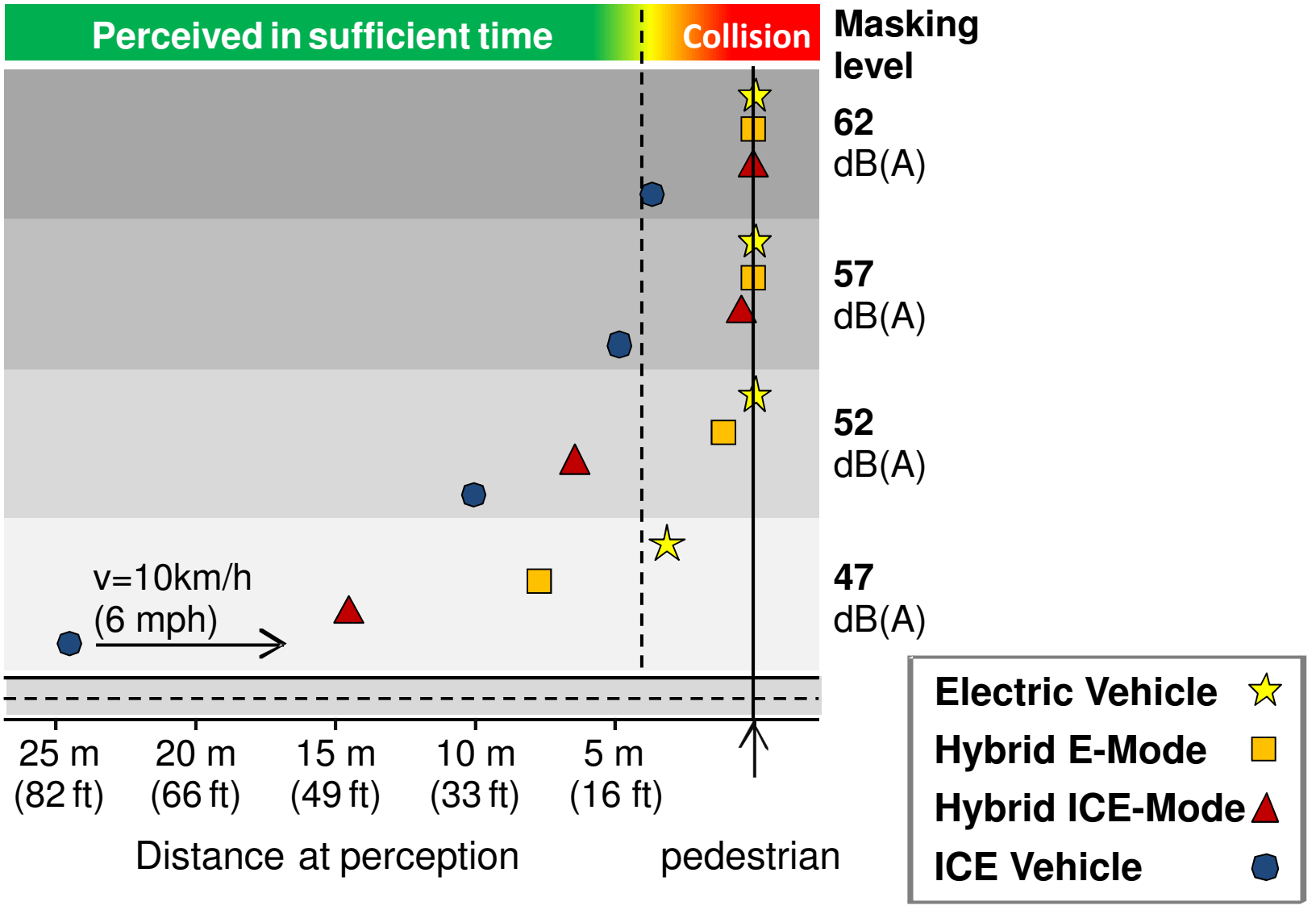
Calculation of masked thresholds according to Fastl & Zwicker (2007)



Perception-distance

Adapted from:Kerber (2008).

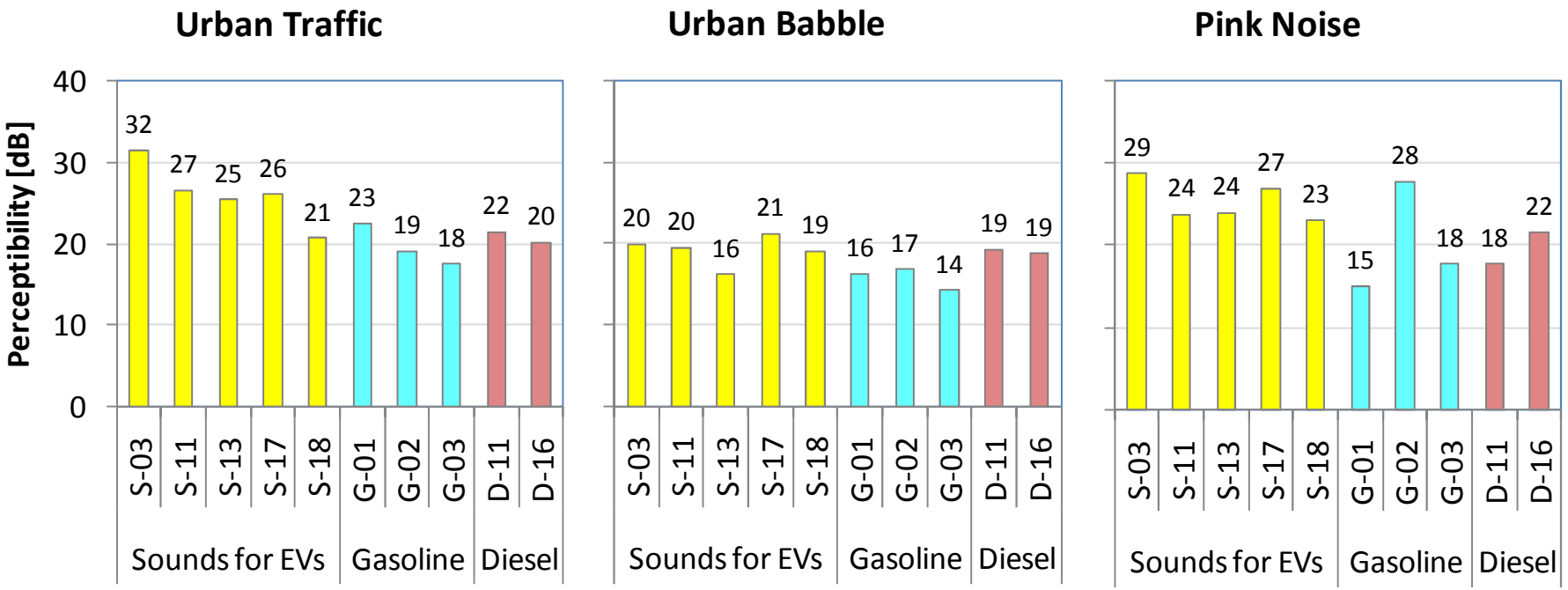
Psychoacoustics.
Algorithmic Prediction of Perceptibility.



Psychoacoustics.

Sound Level dB(A) vs. Perceptibility.

Maskers at 55 dB(A)

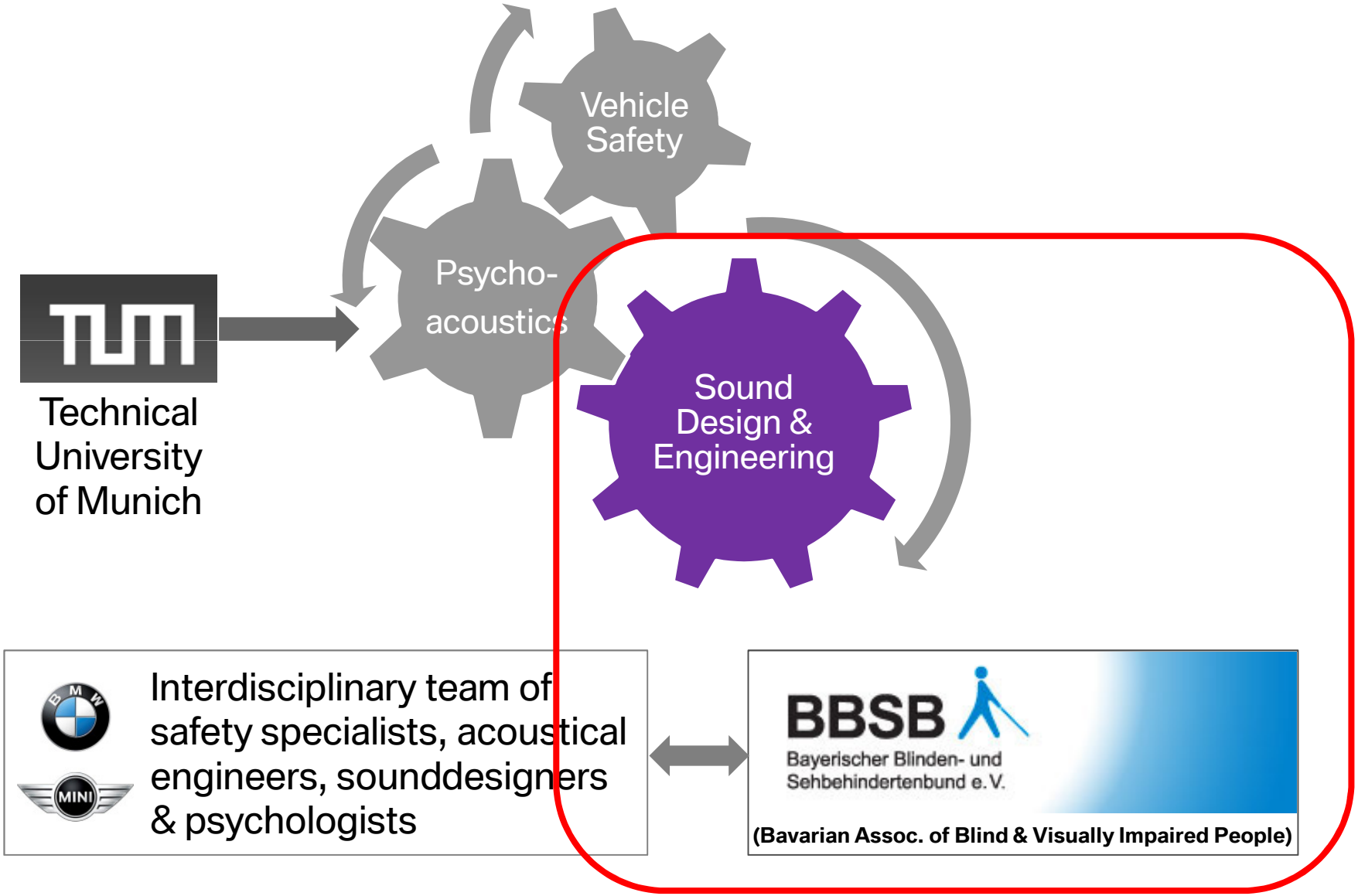


All Vehicle noises at 62 dB(A)

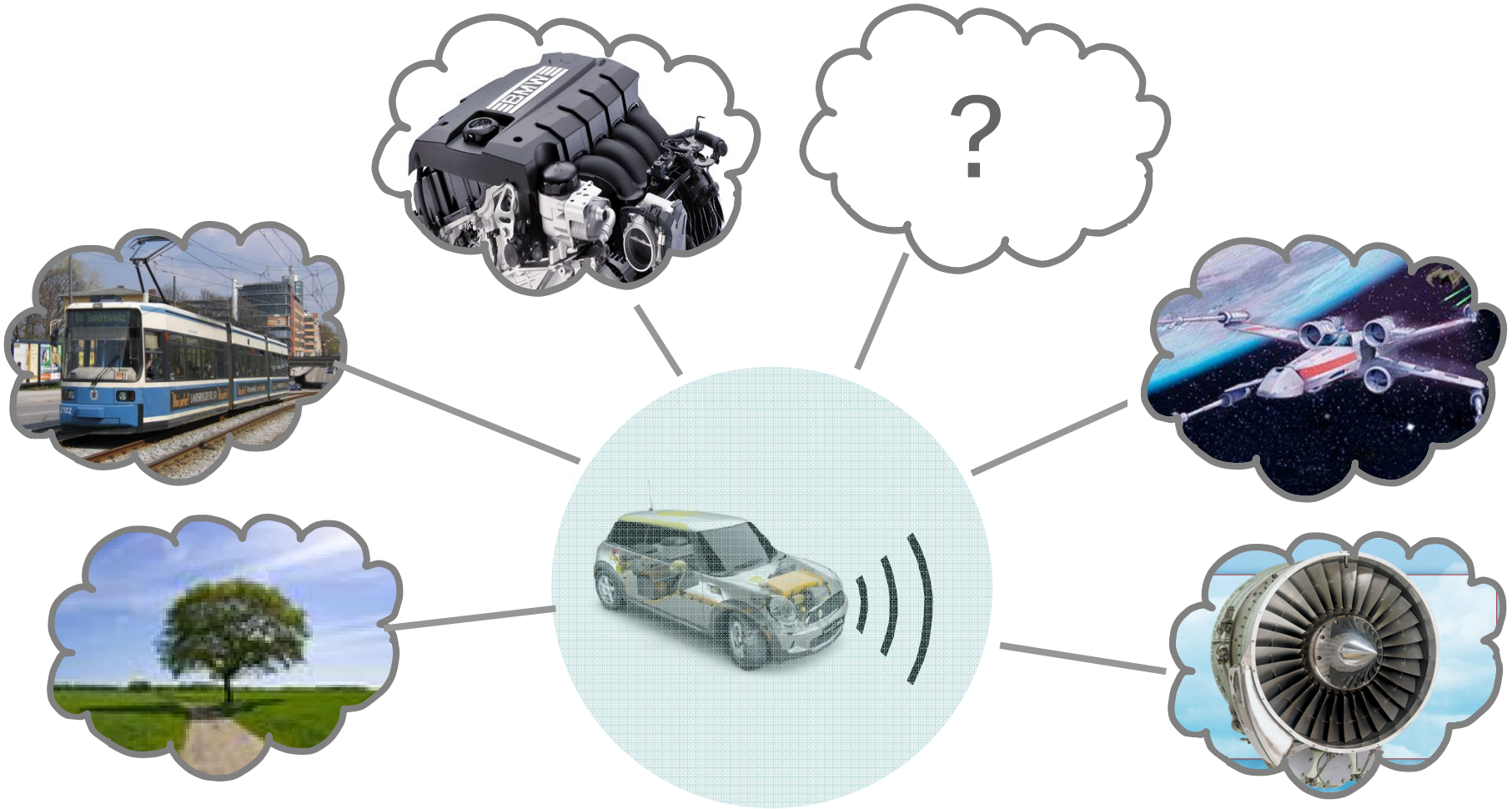
Perceptibility mainly depends on
- **masking properties of the background noise**
- **level and character of the vehicle sound**

=> Sound level dB(A) is not sufficient for evaluation or prediction

BMW Approach and Responsibilities.
Sounddesign & Soundengineering.



Challenges for Acoustics.
Identifiablity of Electric Vehicles.



EVs should shave a distinguishable sound because many of their properties including dynamic performance are different.

Challenges for Acoustics.
Field Study with Blind Community.

- Participants: 5 members of the Bavarian Association of Blind and Visually Challenged people
- Location: vincinity of Munich
- Vehicles/sounds:
  - **Original exterior noise of MINI E**
  - **8 synthetically-produced sounds**
  - **ICE Vehicle (4-cyl. gas. engine)**
- Vehicles passing by at a constant speed of 10 mp/h

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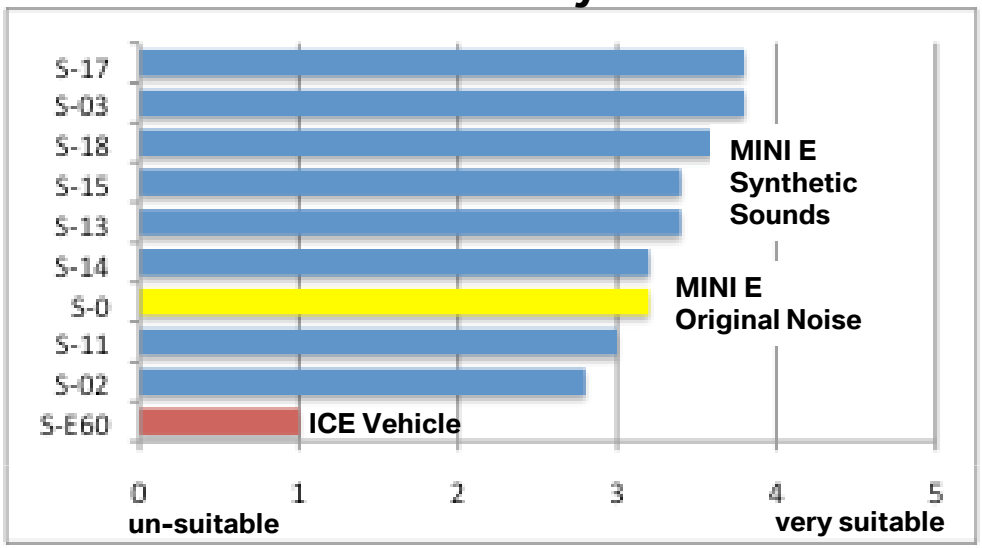
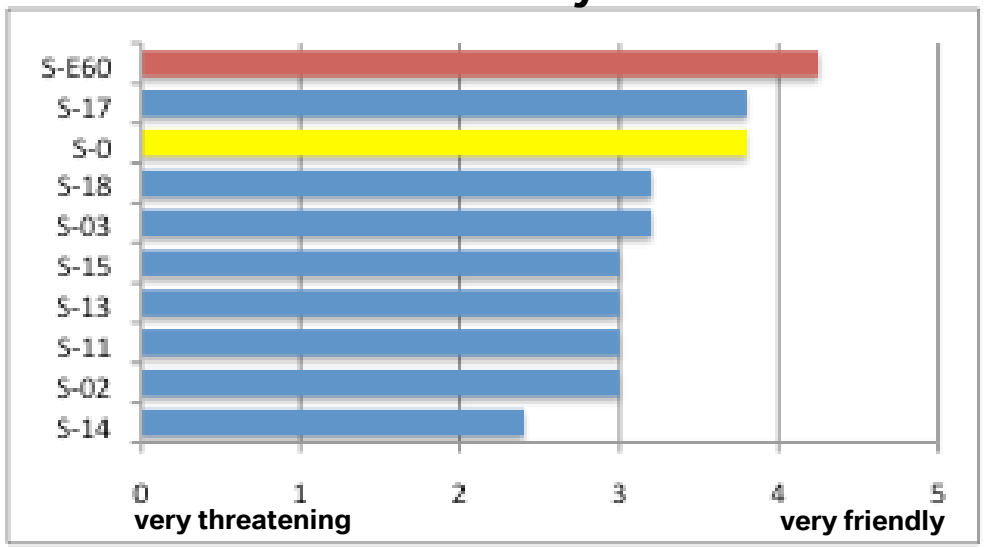
Challenges for Acoustics.
Field Study with Blind Community.

Suitability



Affectivity



- ICE noise not suitable for EVs
- ICE noise is less surprising and therefore may initially appear less threatening due to familiarity
- However, a quick learning effect is expected
- Goal: EV to sound more pleasant than ICE

Challenges for Acoustics.
Requirements for Exerior Noises of EVs.

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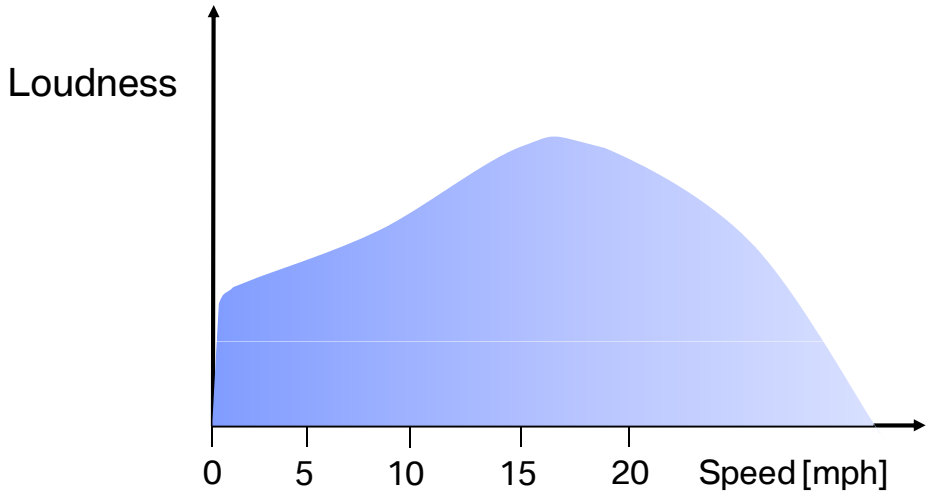
→ **Sound Character**

→ **Level shift**
Pitch shift component
“Attention Catcher”

Challenges for Acoustics.

Perceptible and Pleasant Sound Character with Level Shift.



- Sounddesign with enhanced perceptibility
- Speed-dependent increase of level up to 16 mph (25 km/h)
- Pronunciation of load change through sound level
- Fade out from 16 mph (25 km/h)

Perceptible & pleasant sound character

+

Level shift

+

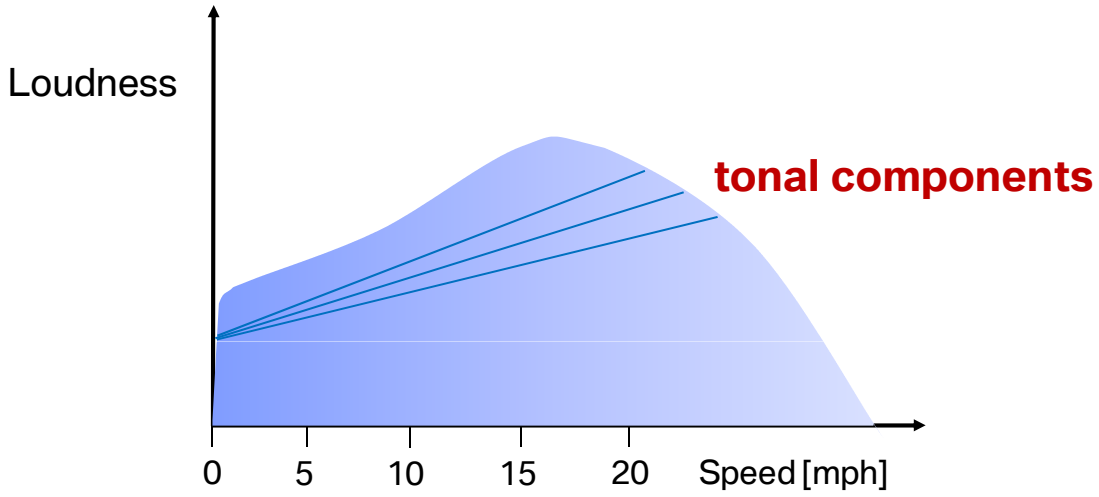
Pitch shift component

+

“Attention Catcher”

Challenges for Acoustics.

Pitch Shift Reflecting Vehicle Dynamics.



- Speed-dependent variation of tonal components
- Frequency range according to hearing sensitivity
- Slope of pitch shift to match subjective impression of acceleration

  (under investigation)

Perceptible & pleasant sound character

+

Level shift

+

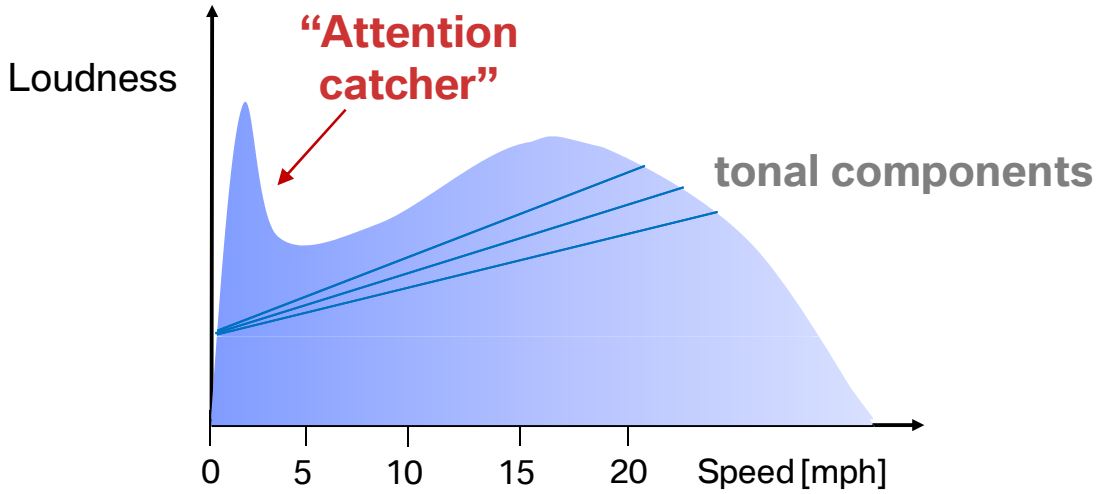
Pitch shift component

+

“Attention Catcher”

Challenges for Acoustics.

"Attention Catcher" for Alerting against Departure.



- Rapid boost of sound level on departure
- Immediate attenuation by analogy to a start-up sound of ICE vehicles
- No idle noise needed

Perceptible & pleasant sound character

+

Level shift

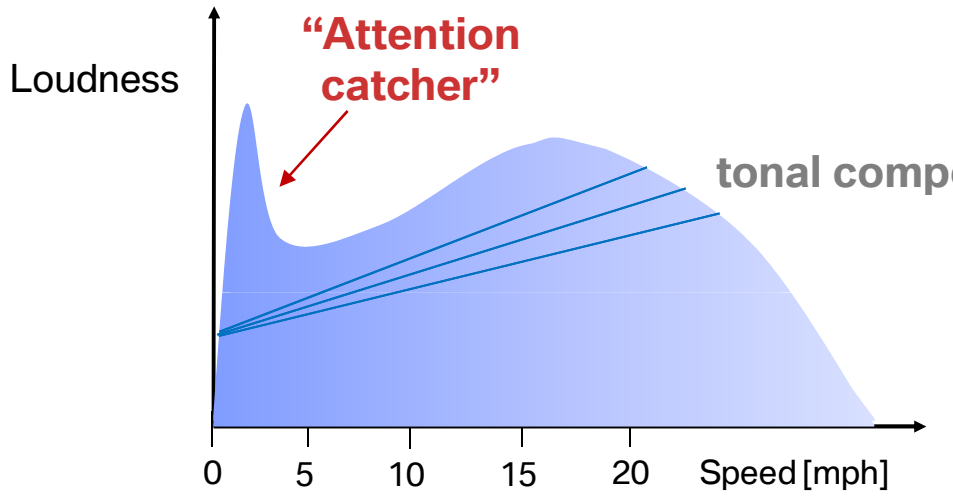
+

Pitch shift component

+

"Attention Catcher"

Challenges for Acoustics.
Recommendation.



“Enhancing safety with an environmentally friendly sound with esthetic value.”

Perceptible & pleasant sound character

+

Level shift

+

Pitch shift component

+

“Attention Catcher”

Thank You for Your Attention.