The design of haptic gas pedal feedback to support eco-driving

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Driving Assessment 2013
ECO-DRIVING?

GOLDEN RULES

MAINTENANCE

MODE AND VEHICLE CHOICE

REAL-TIME, FEEDFORWARD, IN-TRIP GUIDANCE
Visual appears better researched than other modalities, e.g.

– Fuel Economy Driver Interfaces *(Rakauskas et al., 2010)*
– Persuasive In-Car Interfaces *(Meschtscherjakov et al., 2009)*


A slide without a picture, sorry.
Haptic design

- Few compare various haptic throttle feedback designs
- “Haptic Gas Pedal Feedback for Active Car-Following Support” (Mulder, 2007).

Figure 3. The means (horizontal lines) and 95% CI (grey bars) of the mean measured time headway ($THW$) (a) and standard deviation of $THW$ (b) for all subjects.
University of Leeds Driving Simulator
“PLEASE FOLLOW THE GAS PEDAL GUIDANCE TO IMPROVE YOUR FUEL EFFICIENCY”

Cruise 40mph
7% gas pedal

Accelerate 40→60mph
23% gas pedal

Cruise 60mph
7% gas pedal
Standard (non-haptic) pedal
FORCE FEEDBACK
Additional force
Commanded decrease in acceleration
The diagram illustrates the acceleration pedal force (N) in relation to the accelerator pedal travel (%) for different settings:

- **LOW**
- **HIGH**

The lines represent:
- Standard pedal
- Cruise
- Accelerate

The graph shows how the force changes as the pedal travel increases.
STIFFNESS FEEDBACK
Gradient change

accelerator pedal force (N)

accelerator pedal travel (%)
ADAPTIVE STIFFNESS FEEDBACK
Advises increase
Hypotheses

• **Hypothesis 1** – A stiffness feedback system (adaptive or non-adaptive) would provide more effective eco-driving guidance than force feedback

• **Hypothesis 2** – Adaptive feedback would offer more complete and therefore more effective guidance than stiffness feedback

• **Hypothesis 3** – No clear prediction on whether high or low version of a system would perform best
“Which system guided you best to the appropriate pedal angle?”

• Rapid prototyping
  6 interface designs
• Paired comparisons (n = 15)
  Counterbalanced order
• 30 second repeated scenario
• Follow guidance
• 21 participants
  Balanced for age, gender, annual mileage, driving experience
Preference

- Maximum count = 105

LF < HF
LS < HS
LA < HA
LF = LS
LF = LA
LS = LA
HF = HS
HF > HA
HS = HA
Root mean squared pedal error
Root mean squared pedal error

- Main effect of System ($p<.001$)
- Low $>$ High (Force, Stiffness, Adaptive)
- Low /High only: Force $<$ Stiffness and Adaptive

- LF $>$ HF
- LS $>$ HS
- LA $>$ HA
- LF $<$ LS
- LF $<$ LA
- LS = LA
- HF $<$ HS
- HF $<$ HA
- HS = HA
Root mean squared pedal error

Cruise to Accelerate

Accelerate to Cruise
Summary

Subjective

• High intensity version preferred over low
• Between system preference differences more common for ‘high’ version of system
• Force feedback more effective
  – Contrast to Mulder et al. 2007

Objective

• Smaller pedal errors with force feedback
  – Specific to reducing gas pedal pressure?
• High vs. low difference
Prolonged drive

Decelerate scenarios

Workload and acceptance ratings
Scenarios

Village Entry

Bend Entry

S-Bend Entry

Village Centre

Bend Navigation

S-Bend Navigation

Village Exit

Bend Exit

S-Bend Exit
Results – Pedal Error

Speed decrease scenarios

![Bar chart showing error percentages for different scenarios with error bars for visual, adaptive force, and adaptive stiffness conditions. The x-axis represents different scenarios: Village, Bend, and Curve.]
Pedal error

• No comparison with baseline

• Better performance with adaptive haptic-force system than with the adaptive haptic-stiffness or visual systems.

• Speed decrease (cruise to accelerate scenarios) showed a significant effect of system (p<.001)
Acceptance and Workload

**NASA-TLX Score (max. 60)**

- Baseline
- Visual
- Adaptive Force
- Adaptive Stiffness

**System**

**Acceptance Score (max.+2, min.-2)**

- Visual
- Adaptive Force
- Adaptive Stiffness
Hypotheses

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Conclusions

• **Hypothesis 1** – A force feedback system encourages greater accuracy in following gas pedal guidance, especially in deceleration scenarios.

• **Hypothesis 2** – Adaptive feedback does not produce a clear advantage in these testing scenarios...yet.

• **Hypothesis 3** – High version of systems produce better performance and preferred...of the presentation!
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Rapid prototyping (Part 2)

- Visual and visual/auditory
- First and second order
What happened next?
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