The Impact of Sign Placement and Merge Type on Driving Behavior in Construction Zones

Mahmoud Shakouri, Karthy Punniaraj, Laura H. Ikuma, Fereydoun Aghazadeh

Mechanical and Industrial Engineering
Louisiana State University
Construction zones common, dangerous

- Drivers experience work zones every 100 miles\(^1\)
- 21.5% higher rate of crashes than non-construction zones\(^2\)
- 930 fatalities per year\(^3\)

\(^1\)Ullman, 2004, \(^2\)Council et al., 2000, \(^3\)National Work Zone Safety Information Clearinghouse, 2011
Suggestions for improving merge safety

- Reduce vehicles’ speed prior to construction zone entry\(^1\)
- Incorporate forewarning sings for speed reduction\(^2\)
- Use different merge layout\(^3\)

\(^1\)Paolo & Sara, 2012; Weng & Meng, 2011; \(^2\)Migletz et al., 1999; \(^3\)McCoy and Pesti, 2001
How can we improve construction zone safety?

- **Needs:**
  - Understand how traffic design in construction zones impact
    - Driver behavior
    - Perceived workload while driving
  - Understand how a person’s typical driving behavior and personality affect driving behavior in construction zones

- **Current objective:** To determine how driver behavior and workload perception are affected by traffic design in construction zones in terms of
  - Merge type
  - Traffic density
  - Traffic sign distances
Experimental approach

Develop a simulated construction work zone

- 2 merge types
- 2 traffic densities
- 3 sets of sign distances

Conduct experiment with current drivers to assess driving behavior in the construction zone

- # lane changes
- Mean speed (mph)
- Acceleration/deceleration (m/s²)
- Mean braking force (N)
- Drivers’ perceived workload (NASA-TLX factors)
Developing the simulation

- Real-time on-road simulator
- Full-size passenger car
- Create objects and scripted behaviors
Conventional merge

(U.S. Department of Transportation, 2009)
Joint merge

(Idewu, 2009)
Experiment variables

<table>
<thead>
<tr>
<th>Independent Variables</th>
<th>Dependent Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>□ Merge type (2):</td>
<td>1. Number of lane changes</td>
</tr>
<tr>
<td>□ Traffic density (2):</td>
<td>2. Mean speed (mph)</td>
</tr>
<tr>
<td>□ Sign distance (3):</td>
<td>3. Acceleration/deceleration (m/s²)</td>
</tr>
<tr>
<td>□ MANOVA (α = 0.05) for all analyses</td>
<td>4. Mean braking force (N)</td>
</tr>
<tr>
<td></td>
<td>5. Drivers’ perceived workload (NASA-TLX factors)</td>
</tr>
<tr>
<td></td>
<td>a) Mental demand</td>
</tr>
<tr>
<td></td>
<td>b) Physical demand</td>
</tr>
<tr>
<td></td>
<td>c) Temporal demand</td>
</tr>
<tr>
<td></td>
<td>d) Effort</td>
</tr>
<tr>
<td></td>
<td>e) Performance</td>
</tr>
<tr>
<td></td>
<td>f) Frustration</td>
</tr>
</tbody>
</table>
Sample data: NASA-TLX pairwise comparison
Sample data: NASA-TLX ratings
Experiment procedures

30 participant, students, male and female
Age>18 with valid driver’s licence

1. Informed consent, overview, demographic information
2. Driving and personality questionnaires: Manchester Driving Behavior Questionnaire, Driving Anger Expression Inventory, Bortner Type A personality Test
3. NASA-TLX pairwise comparison
4. Motion sickness assessment questionnaire
5. Driving: 12 simulations
   a) 2-3 minutes per simulation
   b) NASA-TLX ratings after each simulation
   c) Motion sickness questionnaire after every other simulation
Joint merge decreases workload

- Mental Demand: p-value = 0.062
- Physical Demand: p-value = 0.677
- Temporal Demand: p-value = 0.007
- Performance: p-value = 0.053
- Effort: p-value = 0.147
- Frustration: p-value = 0.007
Joint merge decreases braking force

![Bar chart showing comparison between Conventional Merge and Joint Merge in terms of Mean Braking Force (N). The p-value is 0.002.]
More lane changes in joint merge

p-value = 0.000
High traffic density increases workload

- Mental Demand: p-value = 0.004
- Physical Demand: p-value = 0.003
- Temporal Demand: p-value = 0.022
- Performance: p-value = 0.210
- Effort: p-value = 0.049
- Frustration: p-value = 0.012

Legend:
- Blue: Low Traffic Density
- Green: High Traffic Density
High traffic density reduces velocity
Increasing sign distance decreases lane changes

\[ p\text{-value} = 0.032 \]
Driving behavior not affected in some cases

**Merge type**
- Deceleration (p=0.742)
- Velocity (p=0.821)

**Traffic density**
- Deceleration (p=0.474)
- Braking force (p=0.526)
- Lane change (p=0.227)

**Sign distance**
- Workload (all 6 components p>0.58)
- Deceleration (p=0.253)
- Braking force (p=0.073)
- Velocity (p=0.067)
Limitations and next steps

Limitations

- Each simulation time too short, but 12 trials fatiguing
- Number of participants
- Simulation’s fidelity to real world driving experience
- Constraints
  - Interstate-type road
  - Day time
  - Good weather
  - “Polite” drivers

Next steps

- Determine how driving behavior changes with
  - Personality type (A/B
  - Driving behavior tendencies (aggressiveness)
- Determine interaction effects between merge type, traffic density, and sign distance
Conclusion: Safer driving conditions and smoother traffic flows are possible

Joint merge: lower driver workload, less brake force

Lower density: lower driver workload

Increased sign distance: fewer lane changes, perhaps less brake force and lower velocity

Impact: Reduce crashes & fatalities by implementing traffic design characteristics associated with safer driving in construction zones
References


References


