

Exploration and Evaluation of Psychological Burden Factors Experienced by Vehicle Occupants in Traffic Environments

- A Data-Driven Approach Using Natural Language Processing -

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Advances in vehicle technologies, including automated driving, have progressed rapidly; however, improving the psychological comfort of drivers and passengers remains important. This requires identifying factors that induce psychological burden and developing quantitative measures. Prior studies have focused mainly on specific conditions, leaving the range of burden-inducing situations insufficiently explored. This study aimed to construct psychological burden scales for drivers and front-seat passengers (DPBQ and PPBQ) using a data-driven approach. Free-description data were classified using BERTopic to obtain an overall understanding of traffic environments that induce psychological burden. Based on the identified topics, questionnaire items were then generated using a large language model (LLM). Finally, the factor structures and validity of both scales were examined.

Firstly, An online survey was conducted with daily drivers aged 18+ under a driver condition (N = 1,100; 550 female; M = 50.8, SD = 11.5) and a front-seat-passenger condition (N = 550; 250 female; M = 49.9, SD = 12.5). Participants provided demographics, driving style (DSQ; driver condition only), and free descriptions of situations that induced negative psychological states. After screening and splitting multi-content responses, 3,527 sentences (1,544 passenger) were analyzed using BERTopic to cluster semantically similar descriptions. The driver and passenger conditions yielded 23 and 18 clusters, respectively, revealing diverse psychological burden factors such as olfactory stimuli and insects/animals. External environmental factors were prominent for drivers, whereas driver-behavior-related factors were prominent for passengers (Table 1).

Next, to construct psychological burden scales based on the identified topics, representative sentences were extracted from the BERTopic-classified descriptions using MMR (690 driver and 270 passenger sentences). Based on these sentences, an LLM generated questionnaire items for each topic, as well as additional items to cover traffic situations not sufficiently represented, resulting in 80 candidate items for the driver condition and 73 for the passenger condition. Online surveys were then conducted with daily drivers aged 18+ for the driver condition (N = 500, M = 51.5, SD = 12.2) and passenger condition (N = 500, M = 51.8, SD = 11.6). For convergent and discriminant validity testing, an additional 948 participants (M = 50.3, SD = 12.2) completed the WSQ and TDPI.

Exploratory factor analysis revealed three-factor structures for both the DPBQ and PPBQ, with cumulative contribution rates of 0.60 and 0.65, respectively (Table 2). The DPBQ comprised factors related to the road/visual environment, surrounding vehicle behavior, and discrepancies from expected driving/in-vehicle conditions. The PPBQ comprised factors related to unstable driver behavior, the road/visual environment, and the in-vehicle environment. Correlations with the WSQ generally exceeded .50, whereas those with the TDPI were below .15, supporting convergent and discriminant validity.

Overall, the data-driven analysis identified diverse psychological burden factors, including those potentially overlooked in previous studies. Based on these findings, the DPBQ and PPBQ were developed to capture both shared and role-specific psychological burdens of drivers and front-seat passengers. Future research will examine individual differences in these psychological burdens.

Table 1: List of Topics Eliciting Psychological Burden in the Driver and Passenger Conditions

(a) Driver

Topic	Topic Name (Summary)	Primary Source of Psychological Burden
0	Traffic signals and intersections	Traffic structure / surrounding vehicles
1	Following distance and tailgating (especially following vehicles)	Surrounding vehicles
2	Vulnerable road users and encounters with them	Surrounding vehicles
3	Traffic congestion	Surrounding vehicles
4	Road road surface conditions	Driving environment
5	Parking and vehicle-width perception	Surrounding traffic / driving operation
6	Odors (inside/outside the vehicle)	In-vehicle / external environment
7	Lane changing	Surrounding vehicles
8	Road visibility in rainy weather	Weather / poor visibility
9	Passengers	In-vehicle environment
10	Noise (inside/outside the vehicle)	Auditory stimuli
11	Narrow roads and oncoming vehicles	Road structure
12	Utry windows and temperature	Road visibility / in-vehicle environment
13	Traffic rule and etiquette violations	Surrounding vehicles
14	Speed mismatch	Surrounding vehicles
15	Large vehicles	Surrounding vehicles
16	Passengers	In-vehicle environment
17	Snowy and icy roads	Weather / driving environment
18	Smartphones	Information devices
19	Presence of animals/insects	Unexpected events
20	Road construction and restrictions	Surrounding traffic
21	Nighttime and glare	Road visibility
22	Sudden maneuvers (jerk)	Surrounding vehicles

(b) Passenger

Topic	Topic Name (Summary)	Primary Source of Psychological Burden
0	Vulnerable road users and inappropriate driving	Vulnerable road users / driver behavior
1	Tailgating	Surrounding vehicles / driver behavior
2	Sudden maneuvers	Driver behavior
3	Delayed driving operations	Driver judgment
4	Frequent lane changes	Surrounding vehicles / driver behavior
5	Speeding (especially on curves)	Driver behavior
6	Smartphone use and conversation	Driver behavior
7	Following distance (especially following vehicles)	Surrounding vehicles
8	Eating, smoking, and odors	In-vehicle environment / driver behavior
9	Driver distraction and drowsiness	Driver state
10	Vehicle interior cleanliness	In-vehicle environment
11	Traffic congestion and route confusion	Traffic conditions
12	Aggressive responses to traffic signals	Driver judgment
13	In-vehicle noise	In-vehicle environment
14	Following too closely	Driver behavior
15	Speeding	Driver behavior
16	Light stimuli	Visual stimuli
17	Rough driving	Driver psychological state / behavior

Table 2 : Factor Loadings from Exploratory Factor Analysis (Driver/Passenger Conditions)

Item (Id#, Topic No.)	Factor 1	Factor 2	Factor 3	R ²
Factor 1 (Road/Visual Environment Burden), $\alpha = .86$				
Driving on a mountain road with continuous curves (c, 1)	0.87		0.87	
Entering a sharp curve with poor visibility (c, 1)	0.85		0.77	
Driving through a long, poorly lit tunnel (c, 1)	0.85		0.87	
Experiencing a sudden change in visibility at a tunnel entrance or exit (c, 1)	0.85		0.86	
Factor 2 (Surrounding Vehicle Behavior Burden), $\alpha = .88$				
Another vehicle moves laterally within the lane, leaving little space from your vehicle (c, 1)	0.86		0.76	
Another vehicle cuts in ahead, leaving a short following distance (c, 1)	0.84		0.75	
Being subjected to unsafe cutting in or overtaking by another vehicle (d, 13)	0.81		0.64	
Factor 3 (Burden Due to Discrepancies from Expected Driving-In-Vehicle Conditions), $\alpha = .89$				
The temperature inside the vehicle is too hot or too cold (d, 12)		0.87	0.53	
Feeling discomfort from the seat or being bothered by unstable objects inside the vehicle (d, 9)		0.71	0.53	0.53
Waiting for another vehicle to start moving at a traffic signal (d, 9)			0.25	0.16
Factor 1 (Unstable Driving Behavior Burden), $\alpha = .85$				
Driving substantially above the speed limit (p, 5)	0.94		0.76	
The driver loses concentration due to smartphone use, distraction, or other activities (p, 9)	0.90		0.76	
Driving at a speed inappropriate for the surrounding conditions (p, 15)	0.90		0.76	
The driver uses a smartphone while driving (p, 6)	0.90		0.69	
Driving that is clearly perceived as speeding (p, 15)	0.90		0.66	
The driver suddenly accelerates or brakes when a traffic signal is about to turn red (p, 12)	0.89		0.59	
The driver appears drowsy or likely to fall asleep while driving (p, 9)	0.89		0.55	
The driver accelerates into an intersection when the signal turns yellow or starts moving before the signal turns green (p, 12)	0.88		0.64	
Sudden steering maneuvers or smooth turning (p, 2)	0.86		0.63	
Factor 2 (Road/Visual Environment Burden), $\alpha = .88$				
Driving through a long, poorly lit tunnel (c, 1)		0.91	0.76	
Experiencing a sudden change in visibility at a tunnel entrance or exit (c, 1)		0.82	0.67	
Driving on a mountain road with continuous curves (c, 1)		0.77	0.64	
Driving on a very dark road with no streetlights nearby (p, 1)		0.74	0.64	
Entering a sharp curve with poor visibility (c, 1)		0.71	0.58	
Factor 3 (In-Vehicle Environment Burden), $\alpha = .74$				
Strong odors from cigarettes or food inside the vehicle (d, 8)		0.89	0.76	
Unpleasant smoke or odors from outside enter the vehicle through an open window (c, 6)		0.82	0.58	
Feeling confined due to close proximity to passengers (p, 1)		0.53	0.33	