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Adverse weather conditions and aggressive driving. What is their impact on driving performance?

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Introduction

- Weather conditions are a significant risk factor for safe driving behavior.
- In Europe, 1.4% of total road crash fatalities are due to fog, 8.6% due to rain, and 0.8% due to snow, sleet or hail.
- Driving under time pressure is associated with aggressive driving and consequently with an increased incidence of crashes.

Research objective

- The quantification of the impact of weather conditions (nice weather, rain, fog, snow) and time pressure on road safety in an urban road, through a driving simulator experiment.
- Examination of key driving performance indicators:
  - driving speed,
  - headway distance,
  - lateral position,
  - steering angle variability,
  - reaction time to the unexpected event,
  - accident probability,
  - other variables
    - driving experience
    - age
    - sex

Experimental procedure (1/2)

Driving simulator

- An experimental procedure was performed on a driving simulator certified by Foerst Driving Simulator FPF

- 42 young volunteers/drivers aged 20-30 years, 25 men (60%), and 17 women (40%)

- Driving on an urban driving environment under:
  - Good weather conditions
  - Heavy rainfall
  - Fog
  - Snowfall (heavily slippery road)

Questionnaire

- driving experience - transportation
- event history
- driver self-assessment

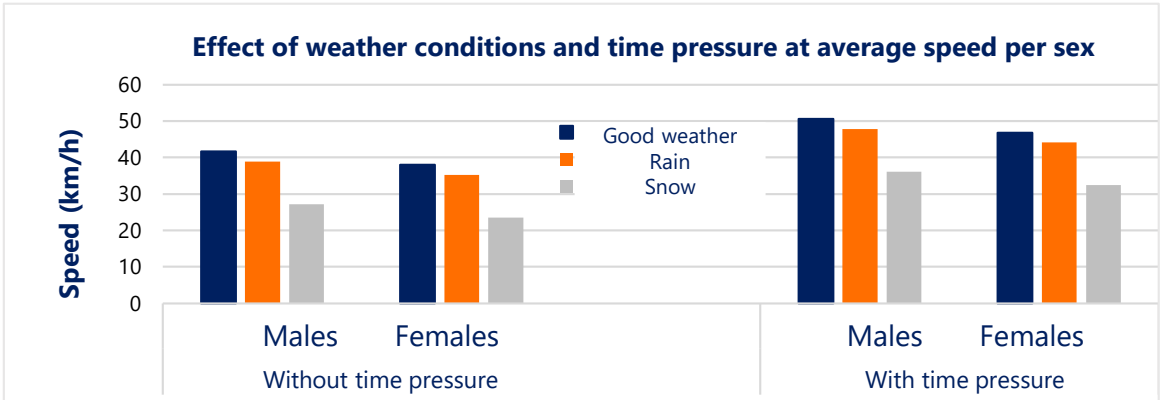
Experimental procedure (2/2)

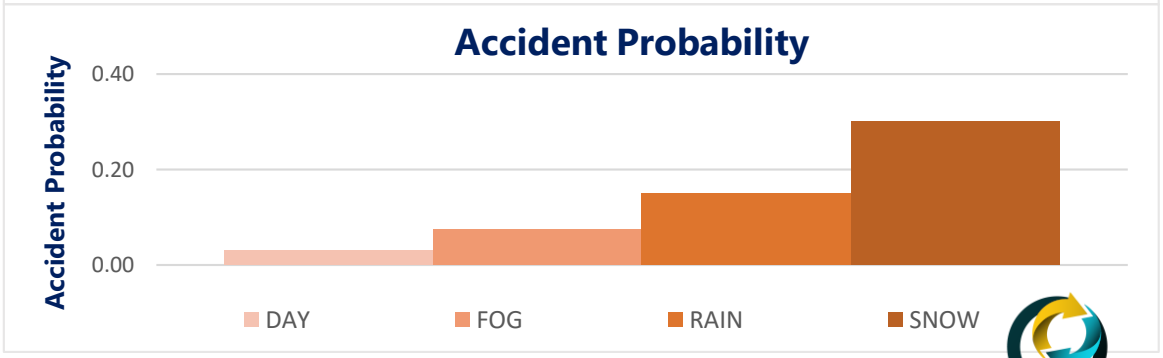
- 15 minutes of practice driving (familiarization) on the simulator
- Driving at an urban road, 1.7 km long with a speed limit of 60km/h.
- Low traffic conditions
- Last 600m. each route was carried out under time pressure (aggressive driving on command by the instructor)
- 3 unexpected events (photo) were scheduled to occur during each session (2 in normal conditions and 1 under time pressure)
- The sequence of routes (rain, fog, etc.) was random
- The points where the incidents were scheduled to occur were not the same between the driving sessions

Creating a database and statistical processing

PersonID	Age	Age Group 2	Age Group	Exp	Nice	Fog	Rain	Snow	Rush	TimeRun	LateralPosition	StdevLateralPosition	AverageSpeed	StdevAverageSpeed	RspurAverage	StdRspurAverage	RalphaAverage	StdRalphaAverage	BrakeAverage	StdBrakeAverage	GearAverage	StdGearAverage	RpmAverage	StdRpmAverage	HWayAverage	StdHWayAverage
D01	24	1	2	2	1	0	0	0	0	02:47	2.251826	1.739835	35.08893	13.39345	2.26088	0.474511	2.721243	3.098521	4.352071	13.72216	2.226036	0.947941	1997.199	609.1944	167.6306	30.91267
D01	24	1	2	2	0	1	0	0	0	02:57	1.184589	0.663182	34.97759	14.99778	3.225763	1.902597	1.879423	2.860583	1.929223	8.435531	2.13727	0.851254	2132.713	662.9461	111.5525	73.02471
D01	24	1	2	2	0	0	1	0	0	02:37	2.035919	1.255838	34.50999	17.70909	2.785473	1.7778	3.467201	3.115425	3.936595	10.64342	1.896914	1.055613	2110.132	873.8418	135.2695	75.55159
D01	24	1	2	2	0	0	0	1	0	03:07	2.424154	1.69779	30.96844	11.07265	2.150012	0.474928	3.08117	3.129261	2.694822	10.96851	1.969253	0.705812	2094.807	541.4327	198.4985	23.48429
D01	24	1	2	2	1	0	0	0	1	00:56	4.890012	0.381335	42.78046	20.40514	2.778882	0.395558	3.04051	3.119741	7.209535	19.9325	2.070041	1.236628	2062.401	898.1748		
D01	24	1	2	2	0	1	0	0	1	01:02	5.002849	0.412051	39.66411	17.61021	2.665533	0.424023	3.607653	3.085605	12.02357	28.08148	2.418854	1.010252	2103.622	653.8614	12.88138	2.841679
D01	24	1	2	2	0	0	1	0	1	00:58	3.32412	1.543339	50.23795	12.46732	4.352433	1.549619	2.516077	3.063294	12.15556	30.56647	2.490028	0.981754	2719.133	587.627	25.19433	12.88827
D01	24	1	2	2	0	0	0	1	1	01:32	2.082174	2.083988	28.94569	12.1409	5.567765	2.076792	3.602608	3.071888	6.396854	19.59821	2.100822	1.226724	1522.434	549.3532	68.41694	24.11994
D02	24	1	2	2	1	0	0	0	0	02:28	2.453611	1.713582	38.48145	14.04739	1.943397	0.436782	3.266395	3.126036	5.564423	17.38092	2.448061	0.97544	2264.44	756.392	117.8936	52.21306
D02	24	1	2	2	0	1	0	0	0	03:00	1.907695	1.346436	34.14282	12.27399	2.506561	1.372982	2.613526	3.085939	4.425055	14.96332	2.256429	0.97177	2070.874	632.9637	89.16734	57.80373

- 42 young drivers
- 80 variables in total
  - (36 driving performance indicators from the simulator and 44 from the questionnaire)
- Descriptive statistical analysis
  - Driving speed is reduced in snow conditions compared to driving in other weather conditions
  - The accident probability shows a significant differentiation between the 4 examined weather conditions
  - Accident probability at an unexpected incident when driving under snow is 30%.





Analysis Methodology

- Multiple Linear Regression Modeling, for Continuous Variables

- Binomial Logistic Regression Modeling, if the dependent variable was discrete

- Model 1: Prediction of **average driving speed**
- Model 2: Prediction of **lateral position**
- Model 3: Prediction of **steering angle variability**
- Model 4: Prediction of **reaction time to an unexpected event**
- Model 5: Prediction of **accident probability due to an unexpected event**
- Model 6: Prediction of **accident probability due to factors other than unexpected events**

Average driving speed and lateral position

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	**(Constant)**	40.563	1.675		24.223	.000
	Exp	1.090	.542	.072	2.011	.045
	Gender	-3.710	.766	-.182	-4.845	.000
	Rain	-2.716	.845	-.119	-3.215	.001
	Snow	-14.456	.852	-.626	-16.973	.000
	Rush	8.896	.694	.445	12.820	.000
	DriveUpTheLimits	2.472	.741	.122	3.336	.001
	TimesDrWRainPerYear	-1.648	.541	-.116	-3.047	.003

a. Dependent Variable: AverageSpeed

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	5.286	.718		7.366	.000**
	Exp	.444	.114	.223	3.887	.000**
	Fog	-.273	.154	-.090	-1.777	.077*
	Rain	-.301	.153	-.100	-1.969	.050**
	Snow	-1.182	.154	-.389	-7.693	.000**
	Rush	1.401	.108	.533	12.982	.000**
	RainDriveToTheEdgeOfTheRoad	-.816	.212	-.162	-3.847	.000**
	FogDriveToTheEdgeOfTheRoad	-.425	.139	-.134	-3.053	.002**
	Age	-.153	.035	-.258	-4.404	.000**

a. Dependent Variable: LateralPosition

- Snow has the greatest impact in the model of mean driving speed as it reduces driving speed significantly.
- Snow and aggressive driving have the greatest impact on the lateral position model, as snow causes more conservative driving near the right border of the road, while rush causes driving closer to the opposite direction of vehicle's movement.

Steering angle variability and reaction time to an unexpected event

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	26.552	5.276		5.033	.000
	Rain	15.871	4.319	.177	3.674	.000
	Snow	43.995	4.354	.487	10.105	.000
	Rush	25.603	3.547	.328	7.218	.000
	AccidentsWDamage	9.880	3.864	.125	2.557	.011
	Exp	-7.822	2.885	-.132	-2.712	.007

a. Dependent Variable: StdWheelAverage

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	879.154	377.927		2.326	.021
	Age	30.360	13.812	.119	2.198	.029
	Gender	126.734	62.862	.111	2.016	.045
	Fog	534.134	85.854	.409	6.221	.000
	Rain	398.605	85.294	.308	4.673	.000
	Snow	349.001	86.190	.266	4.049	.000
	SnowReduceSpeedAndDriveMoreCarefully	-442.896	204.877	-.120	-2.162	.031
	DriveUnderPressure	151.521	85.608	.098	1.770	.078
	AccidentsWDamage	114.457	64.026	.100	1.788	.075

a. Dependent Variable: RT

- Snow has the greatest influence in the model as it increases the steering angle variation significantly - it leads to nervous/unstable driving probably due to the slippery road surface.
- In terms of reaction time at an unexpected event, fog significantly increases the reaction time (by over 0.5 sec), while snow and rain by approximately 0.4 sec.
- This delayed reaction of the drivers can be critical to cause a crash.

Accident probability due to an event and not in an event

Accident probability due to an unexpected event

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	AgeGroup	-.951	.230	17.078	1	.000**	.386
	Fog	.793	.448	3.131	1	.077*	2.209
	Rain	2.084	.424	24.190	1	.000**	8.036
	Snow	2.897	.438	43.700	1	.000**	18.117
	DriveUpTheLimits	-.777	.259	9.023	1	.003**	.460
	DriveCarefully	-.727	.338	4.617	1	.032**	.484

a. Variable(s) entered on step 1: AgeGroup, Fog, Rain, Snow, DriveUpTheLimits, DriveCarefully.

- Fog, rain and snow significantly increase the likelihood of a collision at an unexpected incident.
- Those who self declare that they drive carefully are less likely to cause a crash.

Accident probability due to factors other than unexpected events

Variables in the Equation							
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	Exp	-1,020	,266	14,691	1	,000**	,361
	Gender	-0,539	,318	2,872	1	,090*	,583
	Rain	1,705	,420	16,482	1	,000**	5,503
	Snow	2,811	,418	45,232	1	,000**	16,631
	Rush	0,553	,314	3,100	1	,078*	1,738
	AccidentsWDamages	1,393	,388	12,894	1	,000**	4,027
	TimesDrWRainPerYear	-0,815	,184	19,597	1	,000**	,443

a. Variable(s) entered on step 1: Exp, Gender, Rain, Snow, Rush, AccidentsWDamages, TimesDrWRainPerYear.

- The probability of a crash at another - random point of the route (not in the scheduled events) is also interesting.
- The presence of snow, rain and time pressure, significantly increase the chance of losing control of the vehicle and therefore leading to a crash.

Conclusions (1/3)

- Adverse weather conditions caused improved driving behavior, in terms of "not speeding" and generally more careful driving.
- However, this strategy did not seem to be able to compensate the risk of a crash.
- Snow had the greatest impact on the accident probability at a dangerous event (30%), as well as rain and fog had a considerable impact on mathematical models as well.
- In the absence of an unexpected event, the probability of crash was significantly increased by rush/time pressure due to loss of vehicle control.
- Drivers who self declared that they usually drive above the speed limit seem to be less involved in crashes.

Conclusions (2/3)

- Fog had the greatest negative impact on the reaction time.
- Rain and snow also led to increased reaction time as risk factors.
- Rush resulted in a statistically significant increase in reaction time and in probability of a crash.
- The average speed of the vehicle decreased significantly under snow conditions (15km/h less) and increased considerably under time pressure conditions (average 10km/h more).

Conclusions (3/3)

- Snow and time pressure had a similar effect on the steering angle variability (very increased variability of steering).
- Male drivers exhibit more aggressive behavior, drive at higher speeds and maintain shorter headway distance from the vehicle in front than the more conservative female drivers in all weather conditions.
- Future research efforts could consider additional age groups of drivers and extend the experiment to real driving conditions (at least regarding rain, which is relatively common weather phenomenon in Greece and Europe).
- The application of ITS (Intelligent Transportation Systems) in vehicles seems to be necessary, especially in difficult driving conditions (under heavy rain, fog or snow) to protect the driver from a very probable (as indicated from this study) driving error.

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