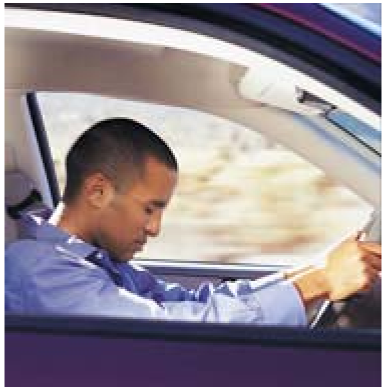
Drowsy Driving Increases Severity of Safety-Critical Events and Is Decreased by Cell Phone Conversation



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Outline

Part 1. Drowsiness prevalance in crashes

Part 2. New estimate of relative crash risk of drowsiness in the 100-Car naturalistic driving study data

Part 3. The interaction between drowsiness and secondary tasks

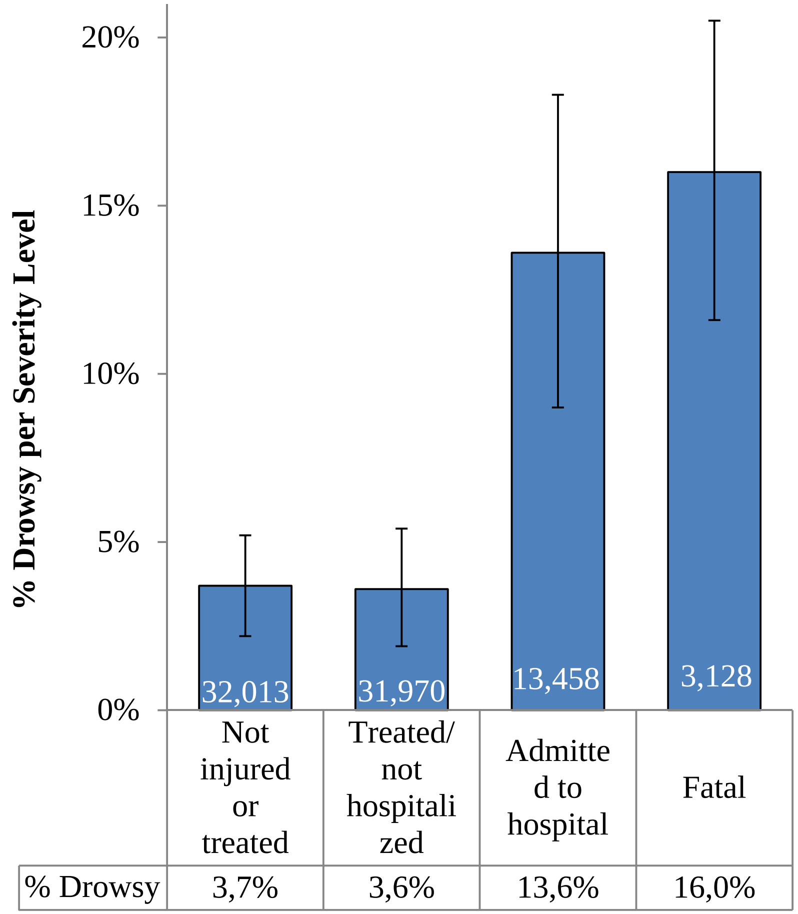
Part 4. The interaction between drowsiness and cell phone conversation

Drowsiness Prevalence in Crashes—Europe

- European studies have estimated drowsiness as a factor in:
  - 24% of fatal crashes (Anselm and Helm 2002)
  - 15% of minor or no injury crashes, but 23% of death and serious injury crashes (Horne and Reyner, 1995)
  - 19% of truck crashes (Evers and Auerbach 2005)

Drowsiness Prevalence in Crashes—U.S.

- U.S. studies have estimated drowsiness as a factor in motor vehicle crashes:
  - 3.6% of fatal crashes (Knipling and Wang 1994)
  - 9.5-21.9% of daytime fatal crashes and 23.6-41.9% of nighttime fatal crashes (Masten et al., 2006)
  - 16% of fatal crashes (Tefft 2012), but 3-4% for minor crashes (see Fig. to right)

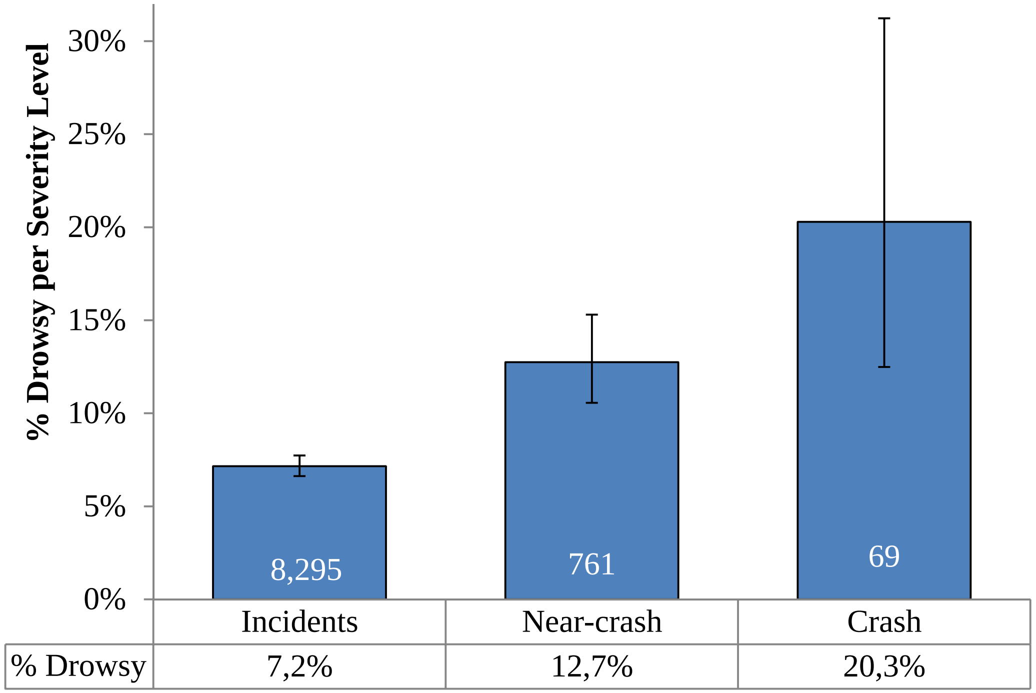


From Tefft, 2012, Table 2

100-Car Naturalistic Driving Study (NDS)

- In the 100-Car study (Klauer et al. 2006), drowsiness was estimated from a 30-second video clip prior to a crash or near-crash event trigger, with only moderate or severe observed drowsiness warranting classification.
- While there are limitations to estimating drowsiness based on such a short time span (Anund et al. 2013), the use of video observations is arguably better than post-crash reconstructions in national crash databases or police reports.

Drowsiness Prevalence in 100-Car NDS



Prevalence of drowsiness observed in 30-second video clips just before incidents, near-crashes, and crashes. The white number at the bottom of each bar is the total number of valid video clips for that severity level (data from the 100-Car study). Errors bars are 95% confidence intervals. Based on 100-Car NDS data from Dingus et al. (2006: Table 2.7) and Guo and Hankey (2009: Table 7).

- There is a higher % of drowsy drivers in higher severity events (20%) than lower severity events (7-13%).
- Consistent with the Horne and Reyner (1995) European study, and the Tefft (2012) U.S. study data cited earlier.

Case-Control Analysis: Drowsiness Increases Severity

A. Horne & Reyner (1995)	Drowsy	Not Drowsy	Total	Prevalence	Odds
Death/Serious Injury	139	477	616	22.6%	0.291
Minor/No Injury	467	2,704	3,171	14.7%	0.173
Total	606	3,182	3,788	16.0%	
OR (95% CI)	**1.69**	(1.35 to 2.10), p = 1.2E-6			
B. Tefft (2012)	**Drowsy**	**Not Drowsy**	**Total**	**Prevalence**	**Odds**
Death/Serious Injury	2,331	14,255	16,586	14.1%	0.164
Minor/No Injury	2,335	61,648	63,983	3.7%	0.038
Total	4,666	75,903	80,569	5.8%	
OR (95% CI)	**4.32**	(2.93 to 6.18), p < 0.001			
C. 100-Car Study	**Drowsy**	**Not Drowsy**	**Total**	**Prevalence**	**Odds**
Crash/Near-Crash	111	719	830	13.3%	0.154
Incidents	597	7,698	8,295	7.2%	0.078
Total	708	8,417	9,125	7.8%	
OR (95% CI)	**1.99**	(1.59 to 2.48), p = 3.1E-10			

- The yellow cells show that the exposure-odds in favor of drowsiness in severe crashes are four times higher than exposure-odds in favor of drowsiness in minor- or no-injury crashes.
- Red: OR > 1, p < .05.

Limitations of Prevalence

- Prevalence alone cannot determine causation, or even whether something is a "contributing factor" – you can only determine the possibility that something is a contributing factor.
- In order to establish causation or say that a risk factor is more than just a *possible* contributing factor, a comparison to an appropriate baseline control is required.
- For example, if drowsiness prevalence is 20% in crashes (as in the 100-Car study), then:
  - Baseline drowsiness below 20% means drowsiness *causes* crashes if no other biases or other risk factors are present
    - Or, is a *contributing factor* for causing crashes if other risk factors are involved.
  - Baseline drowsiness above 20% means drowsiness has a *preventive* effect for crashes, if no other biases or other factors are present
    - Or, is a *contributing factor* for protecting from crashes if other factors are involved.
- Prevalence alone cannot distinguish whether a risk factor (or contributing factor) is a *causal*, *preventive*, or *null* effect.

Prior Studies Using Cases vs. Controls

- Klauer et al. (2006) compared the odds of drowsiness in case video clips to the odds of drowsiness in 5,000 randomly sampled baseline clips, finding a drowsy OR of 4.2.
  - However, the authors used different fault conditions between exposed and unexposed cases, biasing OR upward (Young 2013), and did not match clips by driver or many other factors.
- Guo and Hankey (2009) found a drowsy OR of 4.08 for near-crashes and 7.12 for crashes using unmatched baselines.

Klauer et al. (2010)

- Klauer et al. (2010) matched controls to cases more closely, estimating a drowsy OR of 38.7 for combined crashes/near-crashes.

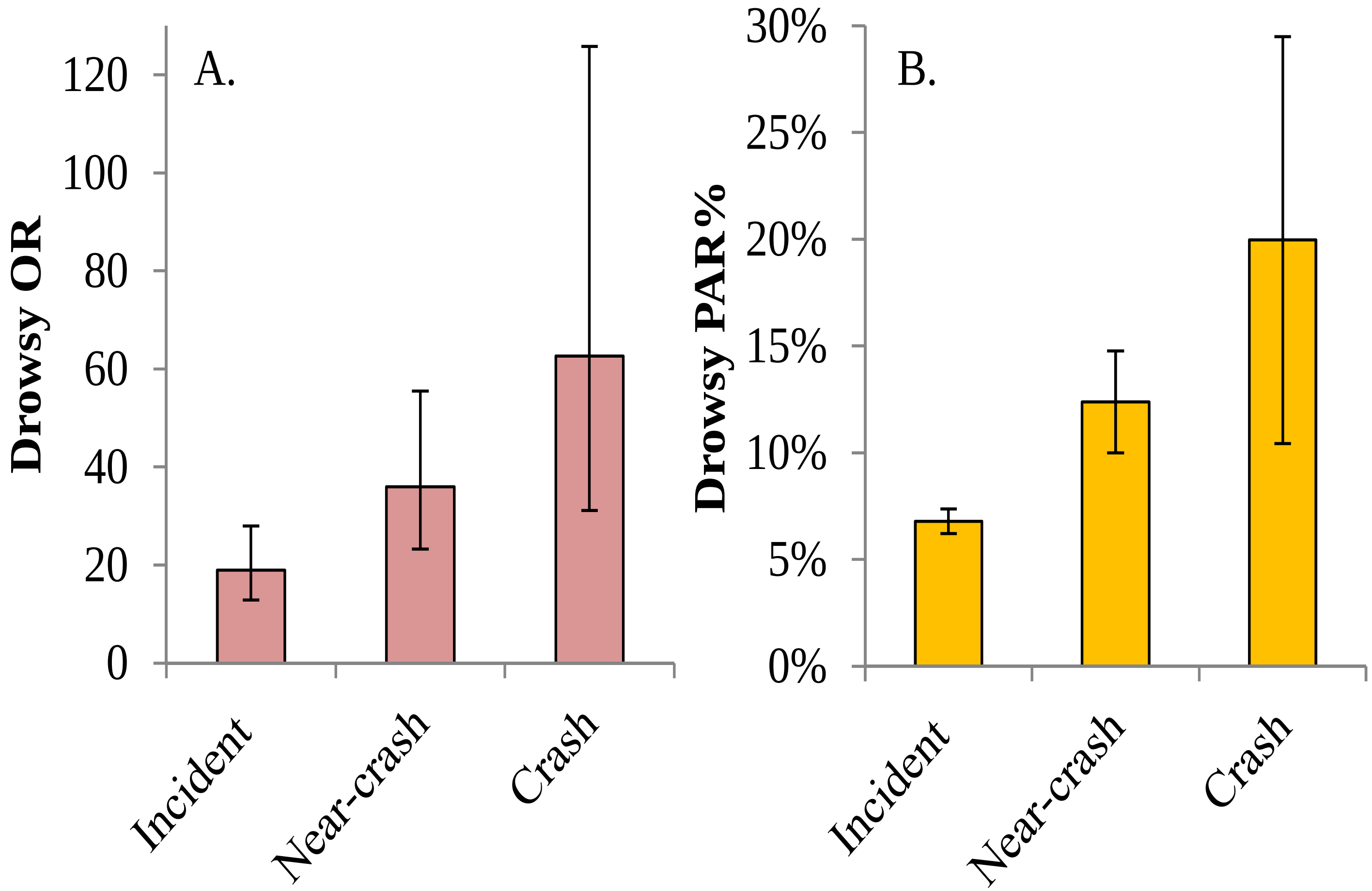
100-Car data replicating the Drowsy OR estimate by Klauer et al. (2010). Red means an OR > 1 with *p* < 0.05

	Drowsy	Not Drowsy	Total	Prevalence
Crash/Near-Crash	111	719	830	13.4%
Matched Baseline	27	6,643	6,670	0.40%
OR (95% CI)	**38.0**	(24.8 to 58.2), *p* = 1.9E-151		
PAR% (95% CI)	**13.0%**	(10.7% to 15.4%)		

New Analysis of 100-Car Data, Separating Crashes, Near-Crashes and Incidents

- The drowsy OR in the 100-Car NDS was re-estimated by comparing the odds of observing drowsiness in "case" clips to the odds of observing drowsiness in matched "control" clips.
- Crashes, near-crashes, and critical incidents from (Dingus et al. 2006; Guo and Hankey 2009) were stratified and separately analyzed, and all cases were analyzed regardless of fault.
- Baseline data was the tabulated data in Klauer et al. (2010), sampled by them to match the GPS location and traffic conditions of crashes and near-crashes.

New Analysis of NDS Data—Results



Drowsy estimates for incidents, near-crashes, and crashes, regardless of fault. Values in Table 3. Error bars are 95% confidence intervals. A. OR estimates. B. PAR% estimates showing 20% population attributable risk for drowsiness in crashes.

New Analysis of NDS Data—Discussion

- The drowsy crash OR of 62.6 is substantially higher than any previous drowsy OR estimate in the traffic safety literature.
  - The crash OR of 62 is higher than the Klauer et al. (2010) crash/near-crash estimate of 38 because it is not combined with the 10 times larger number of near-crashes with a lower OR.
- The PAR% value of 20% for crashes means that if drowsiness could be eliminated while driving, there would be about a 20% reduction in crashes in the general population
  - Indicates that almost every crash with drowsiness in the general population is caused by that drowsiness.

Drowsiness and Secondary Tasks

- Used the 100-Car data from Klauer et al. (2010) with matched baselines, crash/near-crash clips (combined) containing a tabulation of drowsiness and secondary tasks categorized into simple, moderate, or complex difficulty levels.
- The goal was to assess the relative contribution of drowsiness and secondary task complexity to relative crash/near-crash risk, and to assess interactions between the two.

Secondary Task Analysis—Results

- Drowsiness has a higher OR (55) than secondary task complexity groups 0.95-2) after controlling for all interactions.
- The interaction between secondary tasks overall and drowsiness is negligible.

Results of logistic regression analysis of 100-Car data with matched baselines (Klauer et al. 2010), controlling for all grouped secondary task risk factors and their interaction with drowsiness. Red means an OR > 1 with *p* < 0.05; grey means an OR near 1 with *p* > 0.05

Task	OR	[95% CI]		P> |z|
Simple	0.95	0.76	1.19	0.6600
Moderate	1.21	0.96	1.54	0.1100
Complex	**2.22**	1.44	3.43	0.0003
Drowsy	**54.9**	32.34	93.08	7.0E-50
Interaction	0.82	0.45	1.50	0.5100
constant	0.07	0.06	0.08	0.0000

Moderate Secondary Tasks & Drowsiness

A. Not Moderate	Drowsy	Not Drowsy	Total	Prevalence
Crash/Near-Crash	82	354	436	18.8%
Matched Baseline	22	5,194	5,216	0.4%
Total	104	5,548	5,652	
OR (95% CI)	**54.7**	(33.3 to 88.6), *p* = 1.1E-165		
PAR% (95% CI)	18.5%	(14.8% to 22.1%)		
B. Moderate	Drowsy	Not Drowsy	Total	Prevalence
Crash/Near-Crash	10	119	129	7.8%
Matched Baseline	5	1,449	1,454	0.3%
Total	15	1,568	1,583	
OR (95% CI)	**24.4**	(8.2 to 72.4), *p* = 8.8E-17		
PAR% (95% CI)	5.5%	(2.8% to 8.2%)		
C. Crash/Near-Crash	Moderate	Not Moderate	Total	Prevalence
Drowsy	10	82	92	10.9%
Not Drowsy	119	354	473	25.2%
Total	129	436	565	
OR (95% CI)	***0.36***	*(0.18 to 0.72), p = 0.0028*		
PPF% (95% CI)	***16.0%***	*(5.5% to 26.6%)*		
D. Matched Baseline	Moderate	Not Moderate	Total	Prevalence
Drowsy	5	22	27	18.5%
Not Drowsy	1,449	5,194	6,643	21.8%
Total	1454	5,216	6,670	
OR (95% CI)	0.81	(0.31 to 2.16), *p* = 0.68		
PPF% (95% CI)	4.0%	(-14.7% to 22.8%)		

A. Drowsy C/NC OR when not doing a moderate secondary task is 54.7

B. Declines when doing a moderate secondary task to 24.4

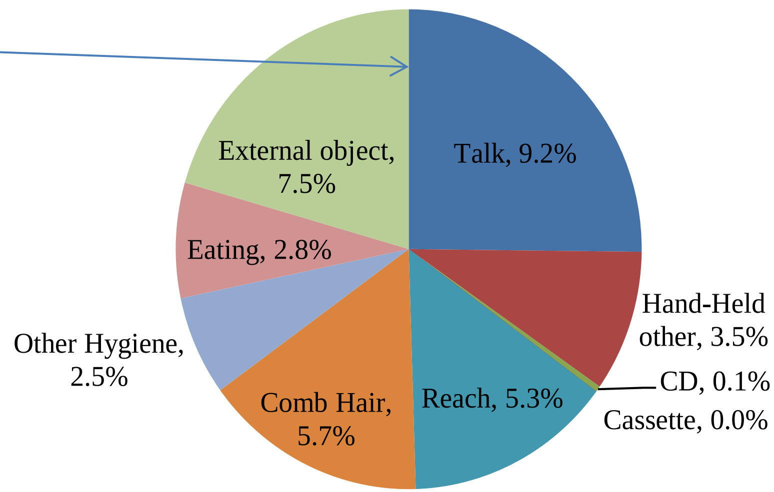
C. Moderate tasks decrease drowsy C/NC odds by about 1/3

D. Moderate tasks have no effect on drowsy in matched baseline

Secondary Tasks Analysis—Discussion

- Previous analysis shows Moderate secondary tasks (as a group) reduce the odds of drowsiness causing a crash/near-crash in the 100-Car event database.
- However, the Moderate secondary task group may be *heterogeneous*, meaning some tasks may contribute more to the interaction with drowsiness than others, particularly Cell Phone Talk (9%).

Prevalence estimates for moderate secondary tasks in the matched baseline 100-Car database (based on Klauer et al. 2010: Figure 15)



Prior Evidence: Auditory-Vocal Tasks Improve Driver Performance

- Simulator
  - Drory (1985) found better brake reaction times, steering reversals, fewer tracking errors, and better choice RT performance when a secondary task involving voice communication was added in a professional truck driver study.
  - Verwey and Zaidel (1999) found fewer run-off-road incidents and crashes when drivers played voice-interactive games under drowsiness-inducing conditions.
  - Takayama and Nass (2008) found that auditory-vocal interaction with a language learning system improved primary driving performance of drowsy drivers.
  - Oron-Gilad et al. (2008) and Gershon et al. (2009) found that auditory-motor trivial games improved monotonous simulator driving and improved alertness as measured by EEG.
  - Atchley and Chan (2011) found that interactive auditory-vocal tasks aroused drivers and helped maintain sustained attention.
- Track
  - Jellentrup et al. (2011) talking on a cell phone helped keep drivers awake during a monotonous drive, and improved alertness as physiologically measured by reduced EEG alpha spindles and shorter blink durations
- Real-World Non-Experimental
  - Baker et al. (2008) found in a focus group that 6 out of 13 (46%) truck drivers said that they used talking on their Citizens Band (CB) radio as a countermeasure to stay awake when drowsy
  - Toole et al. (2013) found in a 100-vehicle NDS study of commercial truck drivers that the highest proportion of mobile device use (accounting for exposure) occurred in the early morning (2 a.m.) time bin. "Results of additional analyses similarly provide support for the hypothesis that truckers may use a mobile device as a countermeasure to drowsiness."

Talk Task in 100-Car NDS

A. Drowsy C/NC OR during Not Talk is 4.12 (unmatched baseline)

B. Declines during Talk to 2.51

C. Talk decreases drowsy C/NC odds by about 7 times

D. Talk decreases drowsy unmatched baseline driving odds by about 5 times

A. Not Talk	Drowsy	Not Drowsy	Total	Prevalence
Crash/Near-Crash	115	656	771	14.9%
Unmatched Baseline	746	17,531	18,277	4.1%
Total	861	18,187	19,048	
OR exact (95% CI)	**4.12**	(3.31 to 5.10), *p* = 1.2E-45		
PAR% (95% CI)	11.3%	(8.7% to 13.9%)		
B. Talk	Drowsy	Not Drowsy	Total	Prevalence
Crash/Near-Crash	1	44	45	2.2%
Unmatched Baseline	12	1,327	1,339	0.9%
Total	13	1,371	1,384	
OR exact (95% CI)	2.51	(0.06 to 17.7), *p* = 0.36		
PAR% (95% CI)	1.3%	(-3.0% to 5.7%)		
C. Crash/Near-Crash	Talk	Not Talk	Total	Prevalence
Drowsy	1	115	116	0.9%
Not Drowsy	44	656	700	6.3%
Total	45	771	816	
OR exact (95% CI)	***0.13***	(0.003 to 0.78), *p* = 0.018		
PPF% (95% CI)	*5.5%*	*(2.8% to 8.2%)*		
D. Unmatched Baseline	Talk	Not Talk	Total	Prevalence
Drowsy	12	746	758	1.6%
Not Drowsy	1,327	17,531	18,858	7.0%
Total	1339	18,277	19,616	
OR exact (95% CI)	***0.21***	(0.11 to 0.38), *p* = 5.3E-09		
PPF% (95% CI)	*5.5%*	(4.5% to 6.6%)		

Auditory-Vocal Tasks—Discussion

- Cell phone conversation reduced the odds of a crash/near-crash caused by drowsiness in the 100-Car study.
- This provides preliminary evidence for real-world validation of the conclusions of experimental results in simulated driving and track studies about reductions in drowsiness from auditory-vocal tasks.
- These findings for passenger vehicle drivers are consistent with the recent NDS result for commercial vehicle drivers (Toole et al., 2013, this conference).

General Discussion

- This new analysis of the 100-car NDS data shows that eliminating drowsy driving will reduce crashes in the population by about 20%.
- Drowsy driving and secondary tasks as a whole have little interaction when their crash/near crash odds are compared to baseline driving odds.
- However, cell phone conversation and the task group of moderately difficult tasks reduce the odds of drowsy-related crashes/near-crashes.

Limitations

- Drowsiness may have been overreported in crashes/near-crashes/incidents in Klauer et al. (2006, 2010) because of hindsight bias, overestimating OR.
  - Can be removed by blind scoring of drowsiness without knowledge of whether it was an event clip or a baseline clip.
- Drowsiness prevalence is likely underreported in national crash databases, especially in daytime driving (Tefft 2012), and especially for microsleeps.

Policy Implications

- Drowsy driving product improvements are needed for detection, alerts, and countermeasures.
- It is recommended that both private and public funding sources in driving safety should transition resources to drowsy driving, to improve the effectiveness of drowsiness detection, alerts, and countermeasures.

Thank you for your attention!

References

- Anselm, D. and Hell, W. 2002. Einschlafen am Steuer. Eine häufig unterschätzte Unfallursache [Asleep at the wheel. A frequently underestimated cause of the accident] *Verkehrsunfall und Fahrzeugtechnik,* 40(3). Available at: http://trid.trb.org/view/2002/C/956208 [Accessed: 1 August 2013].
- Anund, A., Fors, C., Hallvig, D., Åkerstedt, T. and Kecklund, G. 2013. Observer rated sleepiness and real road driving: An explorative study. *PLoS ONE,* 8(5), e64782. Available at: http://www.plosone.org/article/fetchObject.action?uri=info%3Adoi%2F10.1371%2Fjournal.pone.0064782&representation=PDF [Accessed: 5 May 2013].
- Atchley, P. and Chan, M. 2011. Potential benefits and costs of concurrent task engagement to maintain vigilance: a driving simulator investigation. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 53(1): 3-12. Available at: http://dx.doi.org/10.1177/0018720810391215 [Accessed: 30 April 2013].
- Dingus, T., Klauer, S., Neale, V., Petersen, A., Lee, S., Sudweeks, J., Perez, M., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z., Jermeland, J. and Knipling, R. 2006. *The 100-Car naturalistic driving study, Phase II–results of the 100-Car field experiment*. (DOT HS 810 593). [Online: NHTSA, Washington, D.C.]. Available at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/2006/100CarMain.pdf [Accessed: 22 April 2013].
- Drory, A. 1985. Effects of rest and secondary task on simulated truck-driving task performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 27(2): 201-207. Available at: http://dx.doi.org/10.1177/001872088502700207 [Accessed: 1 August 2013].
- Evers, C. and Auerbach, K. 2005. Verhaltensbezogene Ursachen schwerer Lkw-Unfälle [Behaviour-related causes of severe truck accidents]. *Bergisch Gladbach: Bundesanstalt für Strassenwesen BASt.* (174). Available at: http://bast.opus.hbz-nrw.de/volltexte/2011/211/pdf/M174.pdf [Accessed: 1 August 2013].
- Guo, F. and Hankey, J. 2009. *Modeling 100-Car safety events: A case-based approach for analyzing naturalistic driving data*. Blacksburg, Virginia: The National Surface Transportation Safety Center for Excellence. Available at: http://scholar.lib.vt.edu/VTTI/reports/Modeling100CarSafety_Final_041210.pdf [Accessed: 30 April 2013].
- Horne, J. A. and Reyner, L. A. 1995. Sleep related vehicle accidents. BMJ, 310(6979): 565-567. Available at: http://dx.doi.org/10.1136/bmj.310.6979.565 [Accessed: 1 August 2013].
- Klauer, S., Guo, F., Sudweeks, J. and Dingus, T. 2010. *An analysis of driver inattention using a case-crossover approach on 100-Car data: Final report*. (DOT HS 811 334). [Online: National Highway Traffic Safety Administration, Washington, D.C.]. Available at: http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811334.pdf [Accessed: 22 April 2013].
- Klauer, S., Dingus, T., Neale, V., Sudweeks, J. and Ramsey, D. 2006. *The impact of driver inattention on near-crash/crash risk: An analysis using the 100-Car naturalistic driving study data (DOT HS 810 594)*. [Online: National Highway Traffic Safety Administration, Washington, D.C.] Available at: http://www.nhtsa.gov/DOT/NHTSA/NRD/Multimedia/PDFs/Crash%20Avoidance/Driver%20Distraction/810594.pdf [Accessed: 22 April 2013].

References (Cont.)

- Knipling, R. and Wang, J.-S. 1994. Crashes and fatalities related to driver drowsiness/fatigue. [Online: National Highway Traffic Safety Administration, Washington, D.C.]. Available at: http://ntl.bts.gov/lib/jpodocs/repts_te/1004.pdf [Accessed: 22 April 2013].
- Masten, S., Stutts, J. and Martell, C. 2006. *Predicting daytime and nighttime drowsy driving crashes based on crash characteristic models*. Abstract from 50th Annual Proceedings, Association for the Advancement of Automotive Medicine.
- Olson, R. L., Hanowski, R. J., Hickman, J. S. and Bocanegra, J. 2009. *Driver distraction in commercial vehicle operations* (Report No. FMCSA-RRR-09-042). Washington, D.C.: U.S. Department of Transportation. Available at: http://www.distraction.gov/research/PDF-Files/Driver-Distraction-Commercial-Vehicle-Operations.pdf [Accessed: 1 August 2013].
- Oron-Gilad, T., Ronen, A. and Shinar, D. 2008. Alertness maintaining tasks (AMTs) while driving. *Accident Analysis & Prevention,* 40(3): 851-860. Available at: http://www.sciencedirect.com/science/article/B6V5S-4PXMWHV-1/2/3bd5e5dfe29fb17db0d3edbf5c9a31a5 [Accessed: 1 August 2013].
- Takayama, L. and Nass, C. 2008. Assessing the effectiveness of interactive media in improving drowsy driver safety. *Human Factors: The Journal of the Human Factors and Ergonomics Society,* 50(5): 772-781. Available at: http://chime.stanford.edu/wp-content/uploads/2012/09/Takayama.DrowsyDriving_HF2008_prepress.pdf [Accessed: 1 August 2013].
- Tefft, B. 2012. Prevalence of motor vehicle crashes involving drowsy drivers, United States, 1999–2008. *Accident Analysis & Prevention,* 45: 180–186. Available at: http://dx.doi.org/10.1016/j.aap.2011.05.028 [Accessed: 22 April 2013].
- Toole, L.M., Hanowski, R.J., Jackson, T.L.S. and III, W.W.W., "Towards Understanding Mobile Device Use in Commercial Motor Vehicle Drivers: Do Drivers Interact as a Drowsiness Countermeasure?," presented at Driver Distraction and Inattention, Gothenburg, Sweden, 2013.
- VTTI. 2010. 100-Car databases. Available at: http://forums.vtti.vt.edu/index.php?/files/category/3-100-Car-data/ [Accessed: 5 May 2013].
- Verwey, W. B. and Zaidel, D. M. 1999. Preventing drowsiness accidents by an alertness maintenance device. *Accident Analysis & Prevention,* 31(3): 199-211. Available at: http://dx.doi.org/10.1016/S0001-4575(98)00062-1 [Accessed: 5 May 2013].
- Young, R. A. 2013. *Naturalistic studies of driver distraction: effects of analysis methods on odds ratios and population attributable risk.* Paper from the 7th International Driving Symposium on Human Factors in Driver Assessment, Training and Vehicle Design, Bolton Landing, NY, June 17-20, 2013. Available at: http://drivingassessment.uiowa.edu/sites/default/files/DA2013/Papers/077_Young_0.pdf. [Accessed: 1 August 2013].