DAIMLER

Spontaneous vs. gaze shift-induced blinks for assessing driver drowsiness/inattention by Electrooculography

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Contents

Motivation

Drowsiness detection is needed because

- In Germany every fourth car crash occurs due to driver drowsiness (ADAC 2012)
- According to NHTSA 30% of car crashes due to driver drowsiness

➡ Reliable assistant systems are needed to warn drowsy/inattentive driver

Eye blinks are drowsiness indicators, e.g. blink frequency

Eye blinks have different origins:

- Spontaneous
- Non-Spontaneous (simultaneous with fast eye movements)

Number of eye movements increases by e.g. navigation data entry.

➡ Number of non-spontanous blinks increases.

➡ Distinguishing between blinks with different origins becomes interesting.

Do all blinks during driving reflect the alertness of the driver to the same extent?

Literature review

Eye blink features as drowsiness indicator (Hargutt 2003, Schleicher et al. 2008, Dong et al. 2011)

- Increased blink frequency (Stern et al. 1994, Sirevaag and Stern 2000, Hargutt 2003 , Summala et al. 1999)
- Blink amplitude, duration etc. (Dong et al. 2011)

Liang and Lee (2010) reported increased blink frequency in a driving simulator during cognitive and combined (cognitive and visual) distraction.

During driving, blinks mainly occur spontaneously or due to gaze shifts (during a look in the rear-view-mirror).

According to Evinger et al. (1994) :

> "*Gaze-evoked blinks rarely occur when making a saccade to a rear view mirror before shifting lanes, but often accompany the saccade back to straight-ahead position.*"

Eye movements measurement by Electrooculography

Blink (Hammoud 2008)

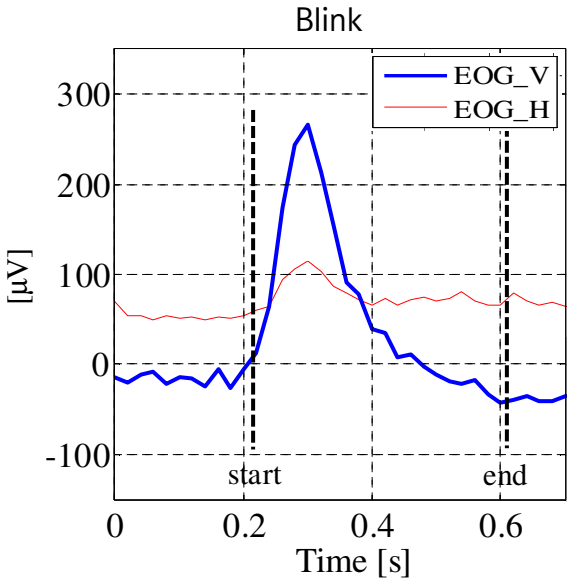
- rapid closing and opening of eyes
- 3 stages: closing, closed and opening

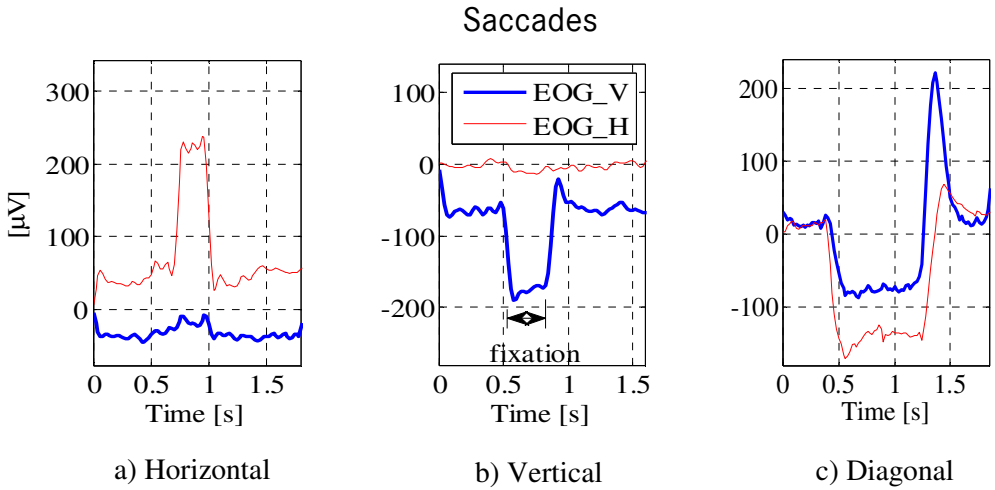
Saccades (Enderle 2010)

- fast movements of both eyes
- changing of the looking direction (gaze shift)
- repositioning the fovea from one image to another one

Fixation

- The time interval between two saccades





a) Horizontal b) Vertical c) Diagonal

Eye movements measurement by Electrooculography

Blink [10]
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- 3 stages: opening, closed and closing

Saccades [11]
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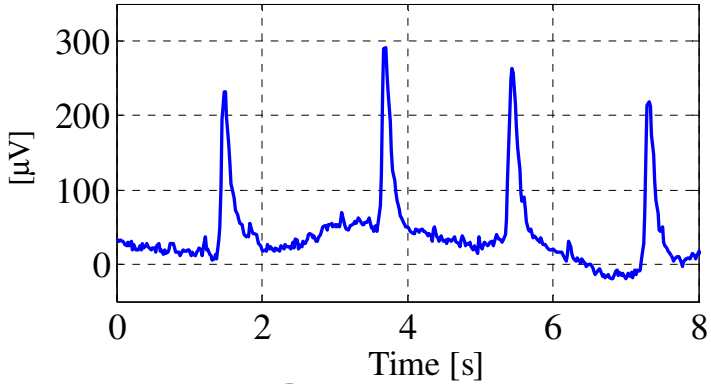
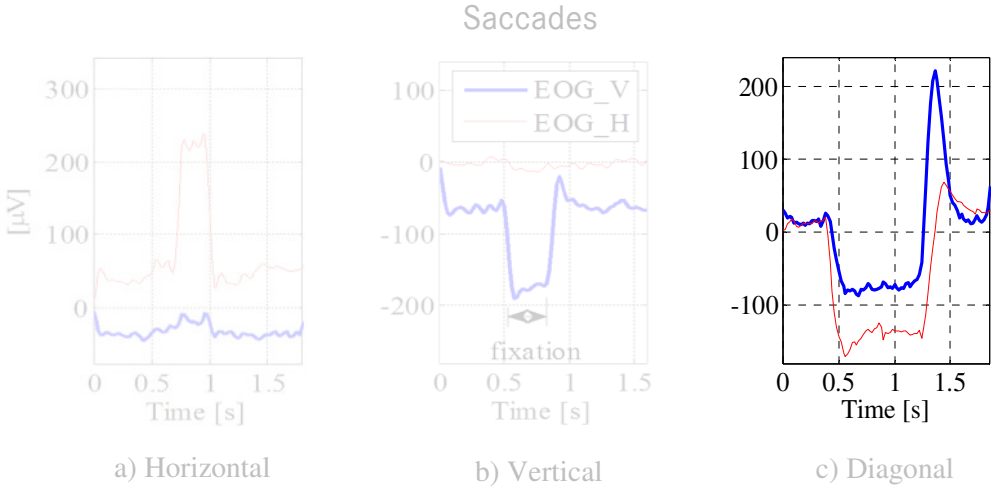


Spontaneous blink



Gaze shift-induced blink

Experimental Design

Experiment 1: real road drive

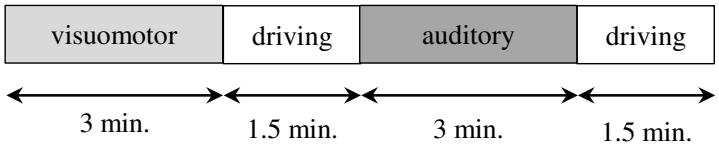
- 26 Participants (power analysis by Sonnleitner et al. (2009))
- Highway A81
- Monotonous conditions
- Driven distance ca. 240 Km within ca. 2 h
- Max. allowed speed 130 Km/h
- Eye movement measurement by Electrooculography (EOG)
  - Sampling rate 250 Hz
  - 6 electrodes
    - 2 for vertical movements & blinks
    - 2 for horizontal movements
    - 2 as reference & ground

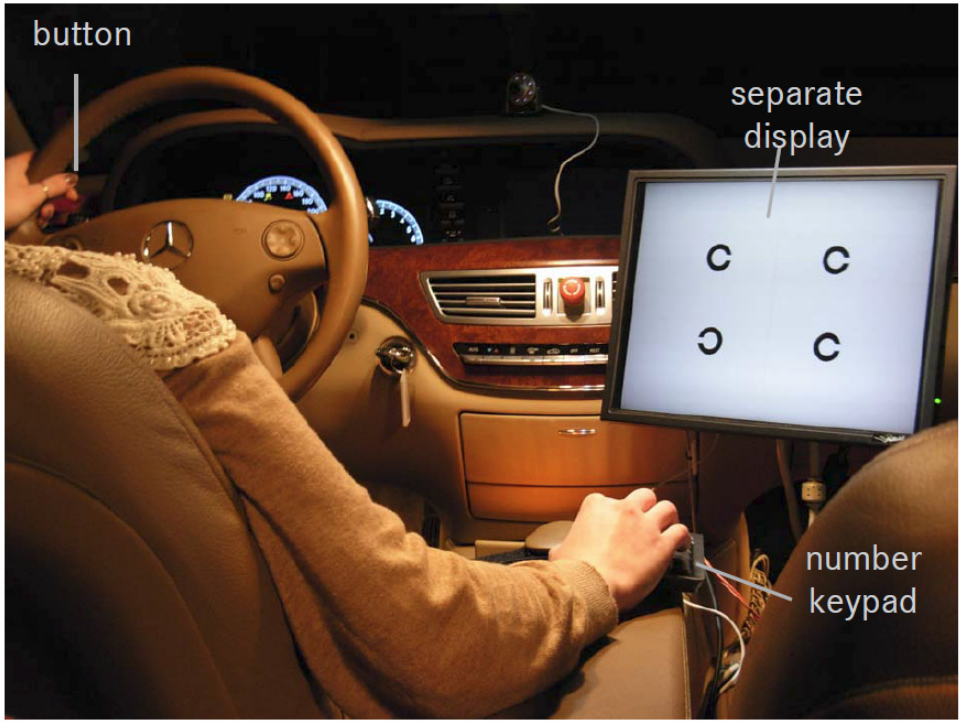
Experimental Design

Experiment 1: real road drive

- Performing primary & secondary tasks on the way back
  - Primary task
    - driving
  - Secondary tasks
    - Visuomotor (fixed position gaze shift)
    - Auditory
  - Each block repeated 4 times

One block of the experiment





(Sonnleitner et al. 2009)

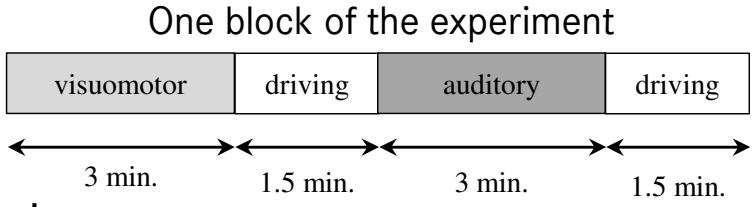
Experimental Design

Experiment 2: Driving Simulator

- 12 Participants
- Moving base simulator, 360° projection screen
- Goal: collecting drowsiness related eye movements
- Very monotonous night drives on highway
- Assessing drowsiness by KSS*
- Driven distance ca. 330 Km within ca. 150 min.
- Max. allowed speed 130 Km/h
- Eye movement measurement as in Experiment 1

*KSS: Karolinska Sleepiness Scale

Results: Experiment 1

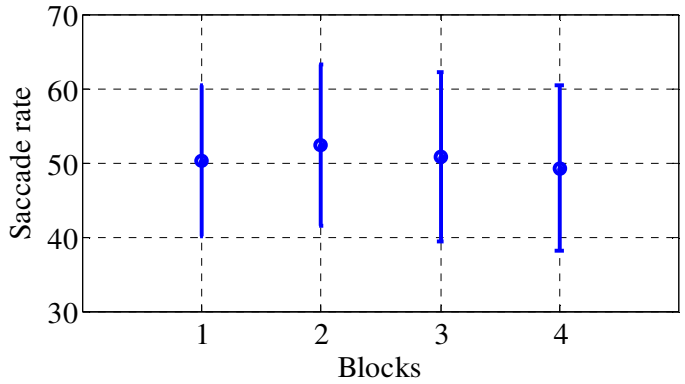


Considering fixed position gaze shifts & all blinks

Time-on-task

	ANOVA	Main effect	
		$F_{3,75}$	*p*-value
Time-on-task	Saccade rate, visuomotor	1.28	0.3
	Blink rate, driving	0.27	0.85
	Blink rate, visuomotor	1.05	0.37
	Blink rate, auditory	1.08	0.36

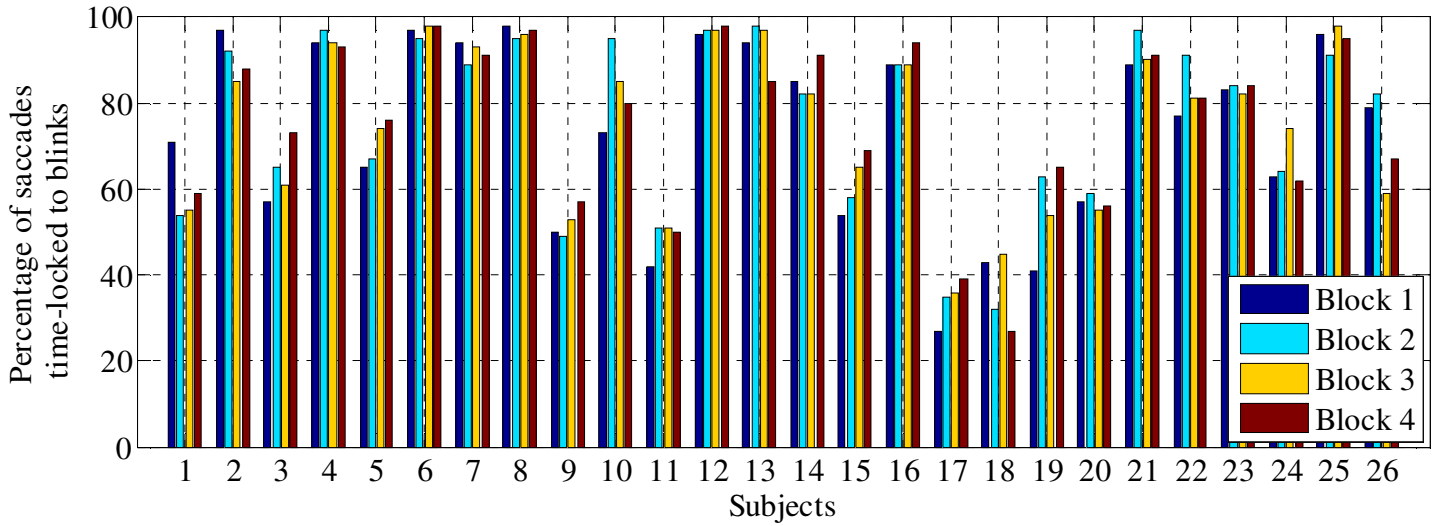
Confidence level = 95%



Saccade rate & blink rate are independent of the variable time-on-task.

Results: Experiment 1

Dependency of the blink occurrence on the gaze shift during the visuomotor task



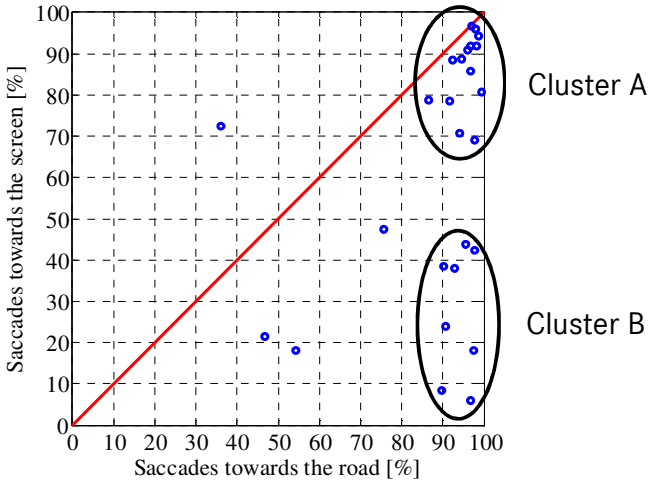
Gaze shift accompanied by blinks

- 14 subjects > 80%
- 9 subjects 50-75%
- 3 subjects < 50%

Gaze shifts induced the occurrence of blinks.

Results: Experiment 1

Dependency of the gaze shift-induced blinks on the direction of the gaze shift

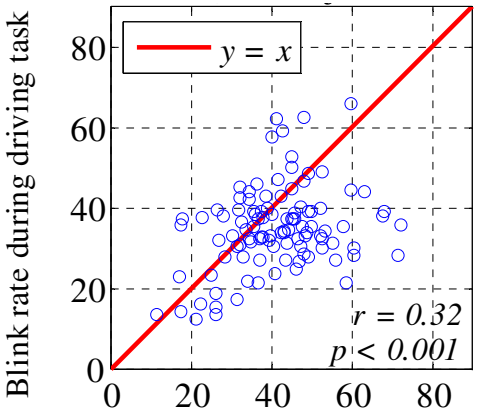


	Nr. of saccades accompanied by blink	
	on-road gaze shifts	Off-road gaze shifts
Cluster A	95%	85%
Cluster B	93%	27%

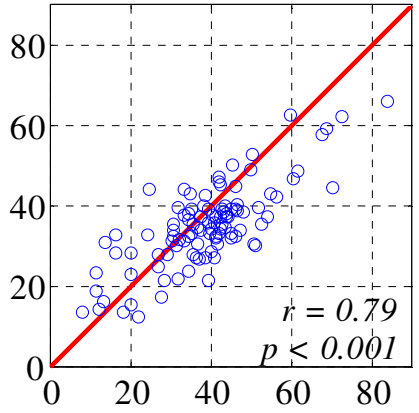
Two behaviors: direction-*dependent* gaze-shift induced blinks & direction-*independent* gaze-shift induced blinks

Results: Experiment 1

Impact of secondary tasks on the blink rate



Blink rate during visuomotor secondary task

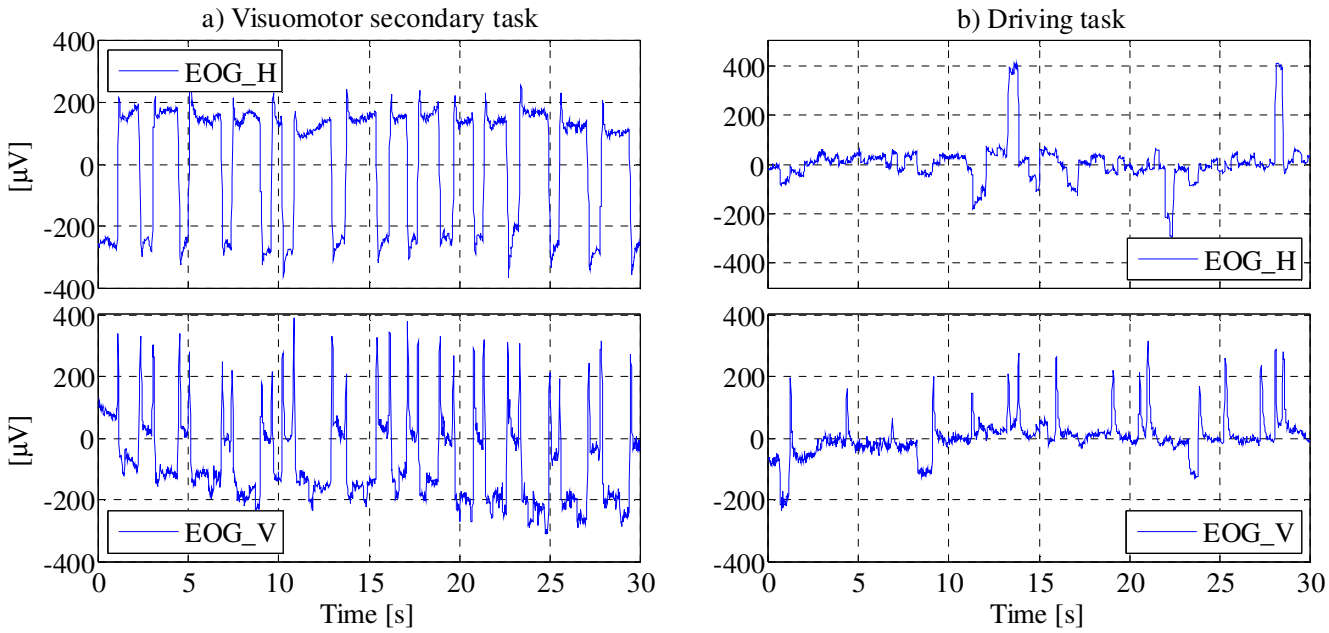


Blink rate during auditory secondary task

Visuomotor secondary task affect the blink rate to a larger extent & leads to the increase of it.

Results: Experiment 1

Modulation of blink frequency during the visuomotor secondary task



During visuomotor secondary tasks, saccade frequency specifies blink frequency.

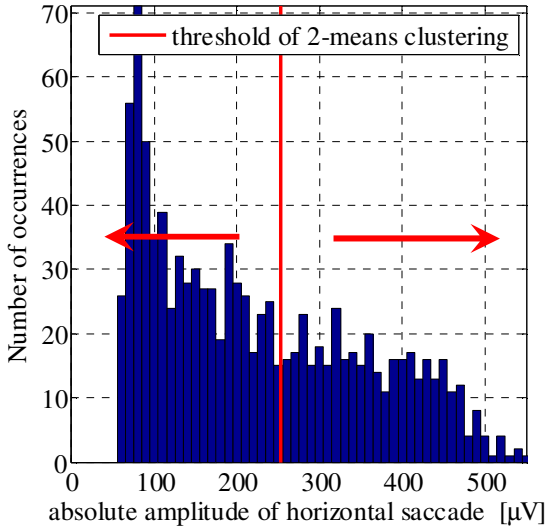
Results: Experiment 2

Considering gaze shifts between various positions

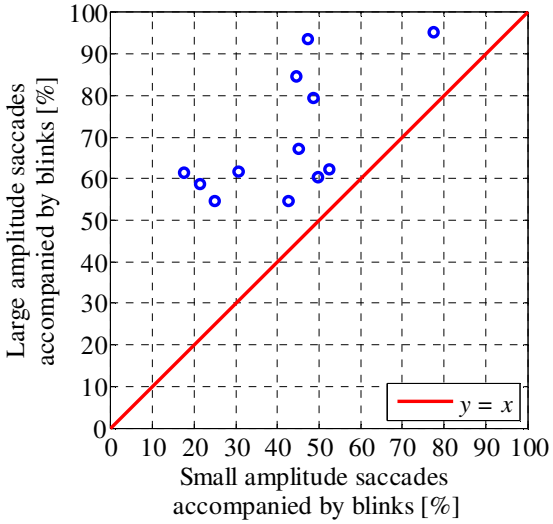
Amount of gaze shift responsible for the occurrence of gaze shift-induced blinks

- Dividing saccades into 2 groups: Small/large amplitude saccades

Small amplitudes



Large amplitudes



The larger the amount of the gaze shift, the more probable the blink occurrence.

Conclusion and Future Work

Summary

- 2 experiments: real road drive & driving simulator
- Studying the effect of secondary tasks on the blinking behavior
- Studying the impact of the voluntary saccades on the blinking behavior

Conclusion

- During a visuomotor secondary task (navigation system's demand), gaze shifts induce the occurrence of blinks.
- On-road gaze shifts are accompanied by blinks to a larger extent.
- Secondary tasks affect the blink rate. Visuomotor task increases it more profoundly.
- Probability of bilking during large amplitude saccades is higher.

➡ **Assistant systems based on blink behavior (e.g. frequency) should handle non-spontanous blinks differently.**

Future work

- Combining both experiments to study the effects of performing secondary tasks on the blinking behavior over longer time.

Thanks for your attention. Questions?