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Assessing driver state –  
Neurophysiological correlates of attentional shift during real road driving

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## Agenda:

- Motivation
- Introduction to neurophysiologic based measures
- Theory on attention
- Experiment description
- Results
- Discussion



## Motivation:

### Cause of Fatal Accidents



*Proceedings of the 40th Annual Meeting of the Association of Automotive Medicine, Canada 1996*

## Motivation – Assistance Systems

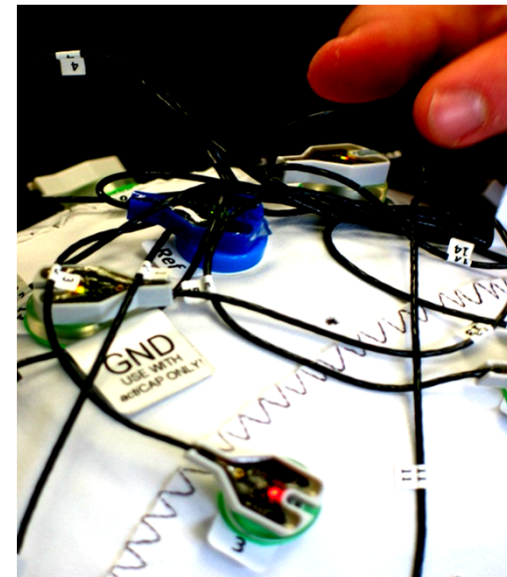
- Further development of Attention Index
- Differentiation: attentive - distracted
- Tool to develop and validate driver assistance systems

### Description with neurophysiological measures (EEG)

- objective
- indicates mental workload
- high temporal resolution
- independent of experimental design

### Description with behavioural parameters

- Effects of secondary tasks on driving behaviour (Attention Assist)



## Introduction to neurophysiologic based measures:

### **Main Challenge:**

Various studies reported about correlation of alpha-band power and distraction

Real traffic vs. lab [artifacts, noise]

Wide range of frequencies might be affected from biological and technical noise

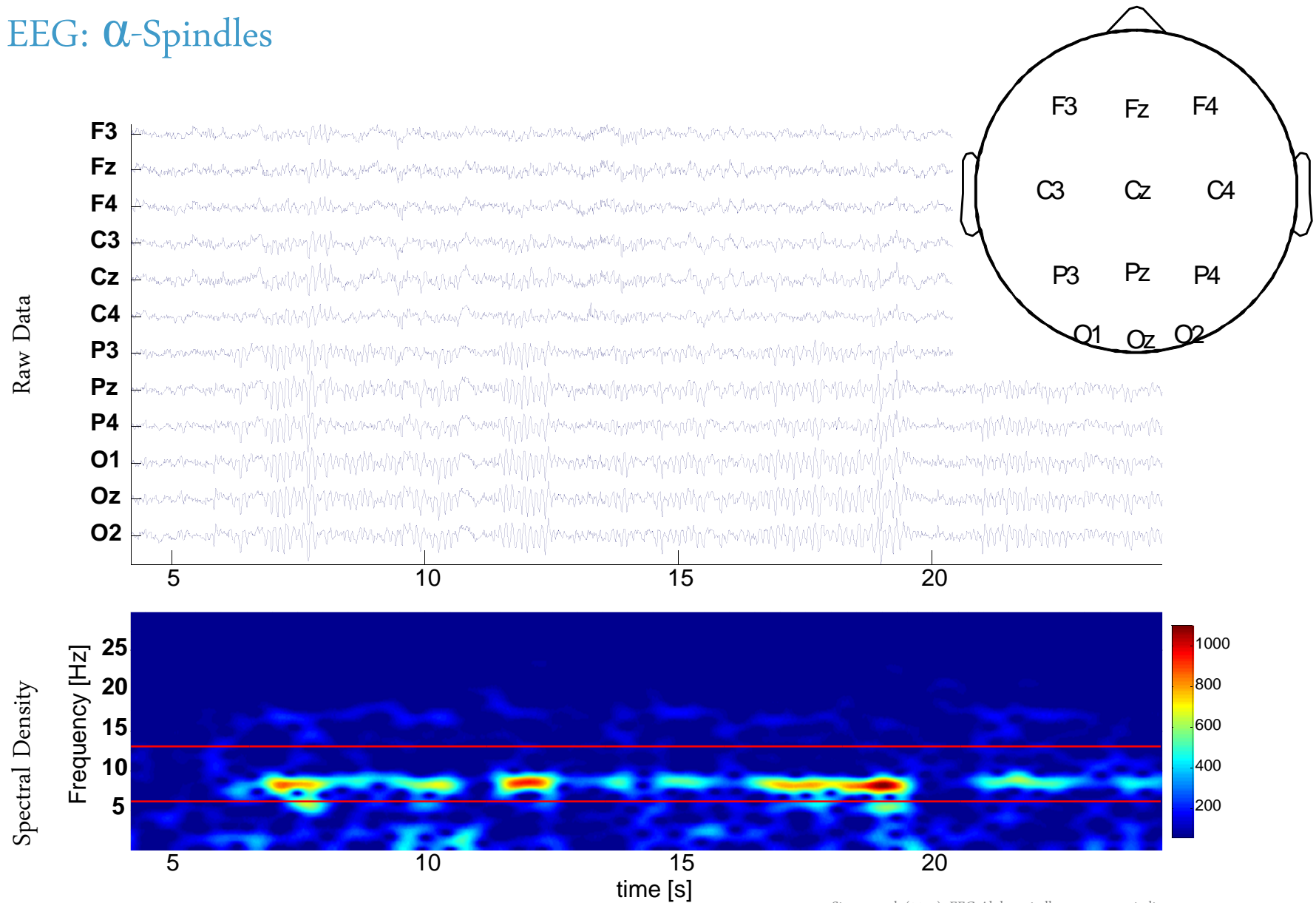
Consequently, changes in alpha-band power alone can not be unambiguously attributed to neural factors.

Focus on spectral microstructures within the alpha-band indicative for attention and fatigue (e.g. Kecklung & Akerstedt 1993; Papadelis et al., 2007).

Short (500 ms to several seconds) narrowband „bursts“ of alpha activity, which we call “*Alpha Spindles*”.

Simon et al. (2011). EEG-Alpha spindle measures as indicators of driver fatigue  
under real traffic conditions. (Clin. Neurophysiol.)

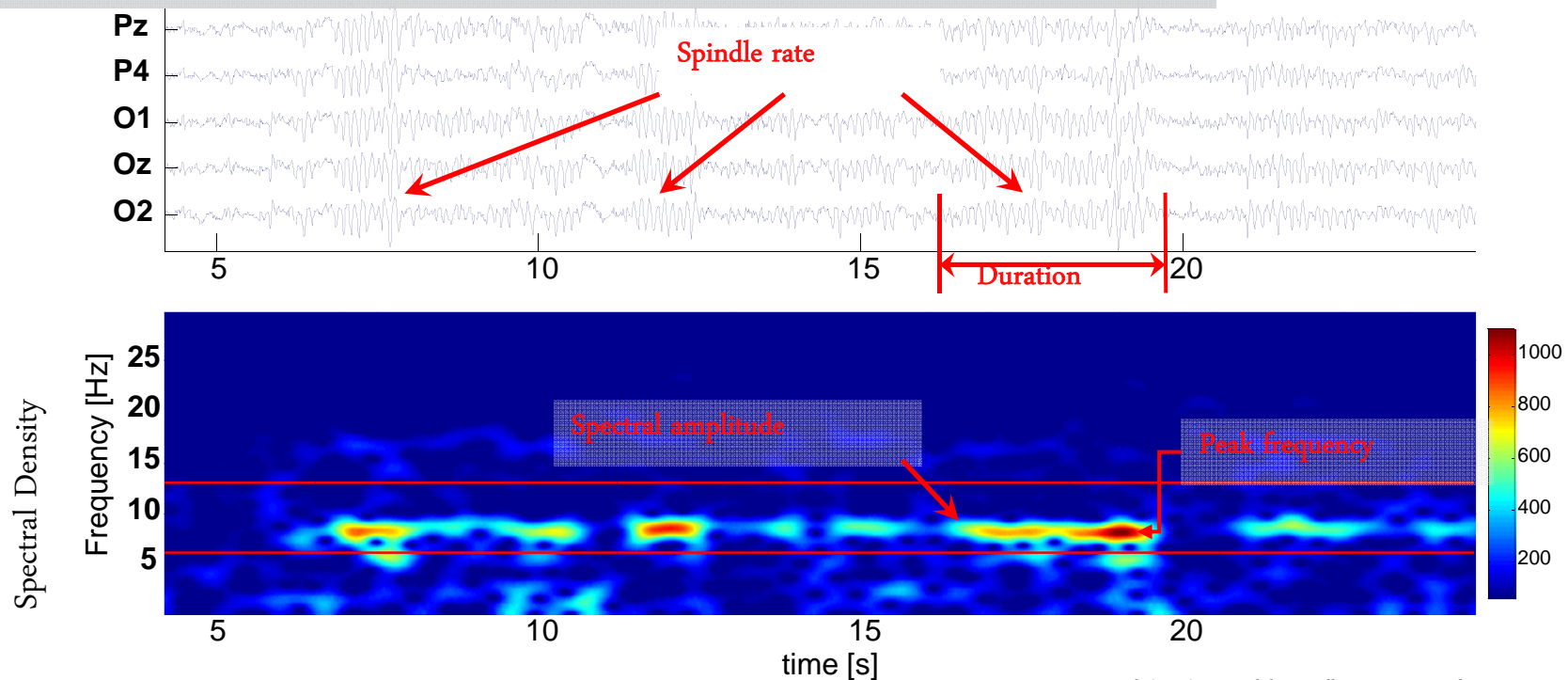
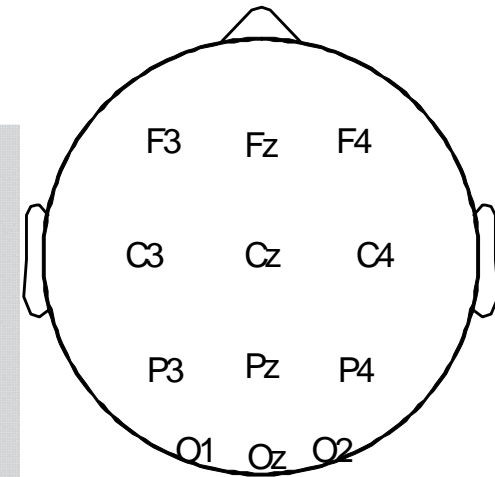
## EEG: $\alpha$ -Spindles



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Parameters of  $\alpha$ -spindles:

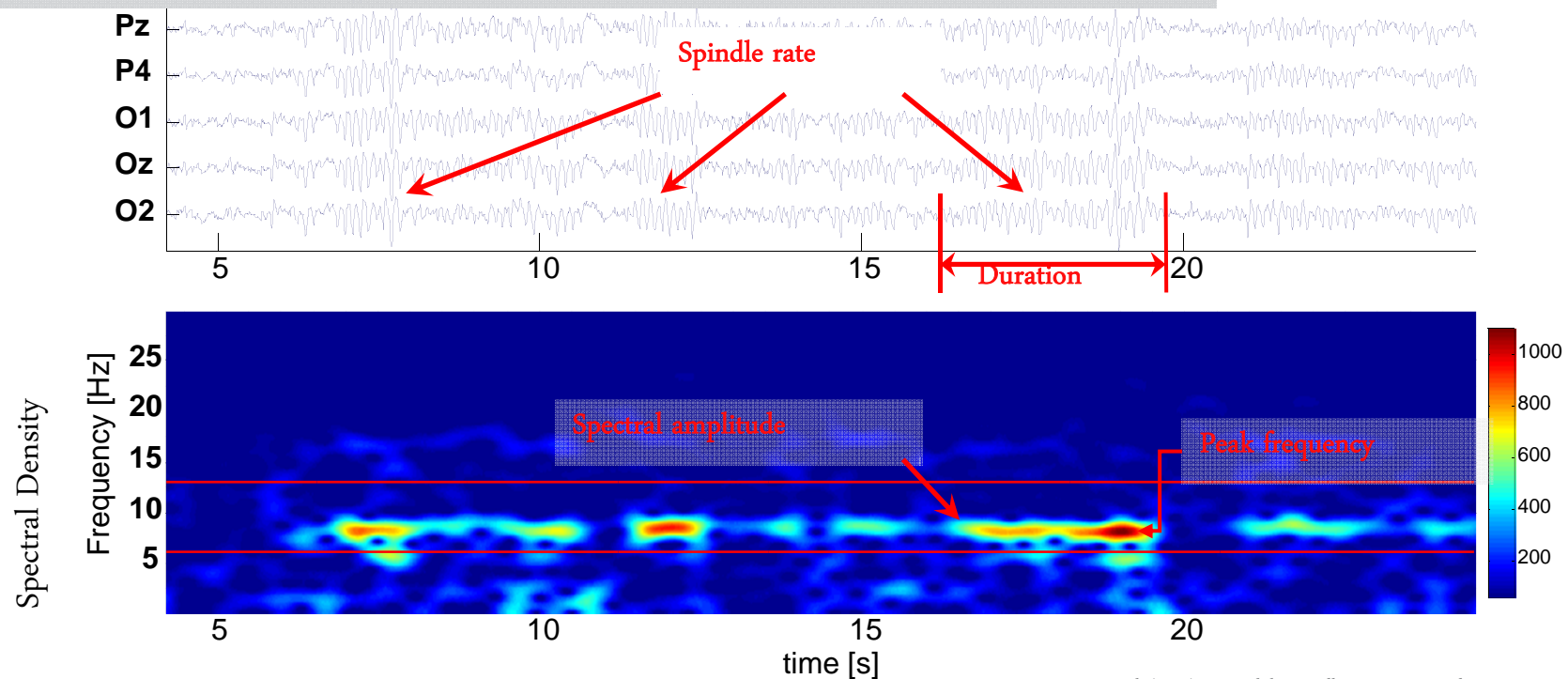
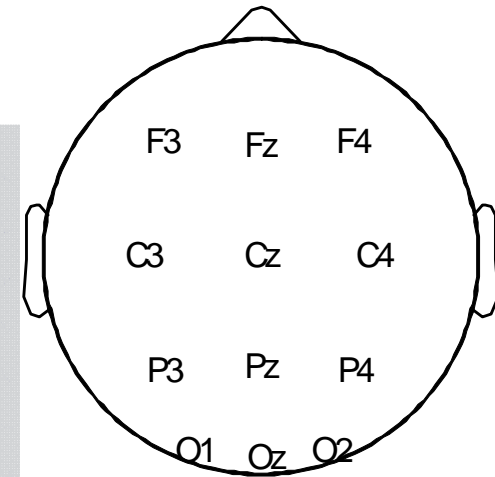
- Peak frequency
- Amplitude
- Duration
- Spindle rate (occurrence per min)



## EEG: $\alpha$ -Spindles

Advantages of  $\alpha$ -spindles:

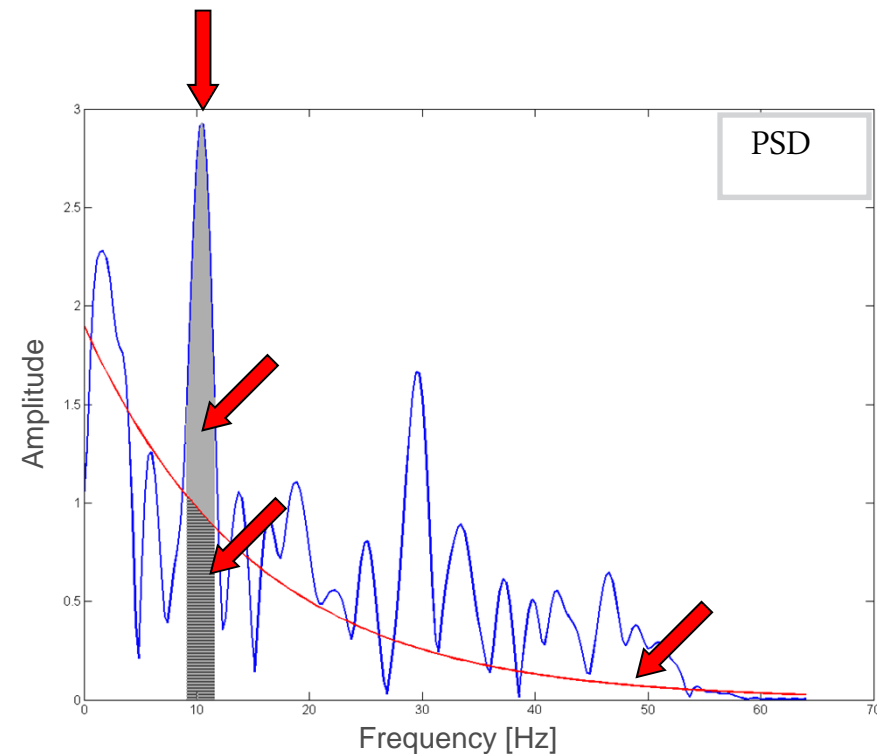
- Nonstationarity of EEG is taken into account
  - Narrow frequency band (7-13 Hz)
- makes it robust against artifacts (biological & technical)





## Detection of $\alpha$ -Spindles:

1. Fast Fourier Transform (FFT) of overlapping segments (1s) for each channel
2. Find maximum within  $\alpha$ -band
3. Noise approximation  
by exponential fit ( $1/f_{\text{noise}}$ )
4. Criteria for  $\alpha$ -spindles:
  - SNR > threshold (factor > 2)
  - Duration > 500 ms (4 cycles)
  - No frequency change ( $\pm 0.5$  Hz)
5. Works in real time:  
  
Delay depends on size of  
the analysis window.  
  
Typically: 60 s width, 1 s step



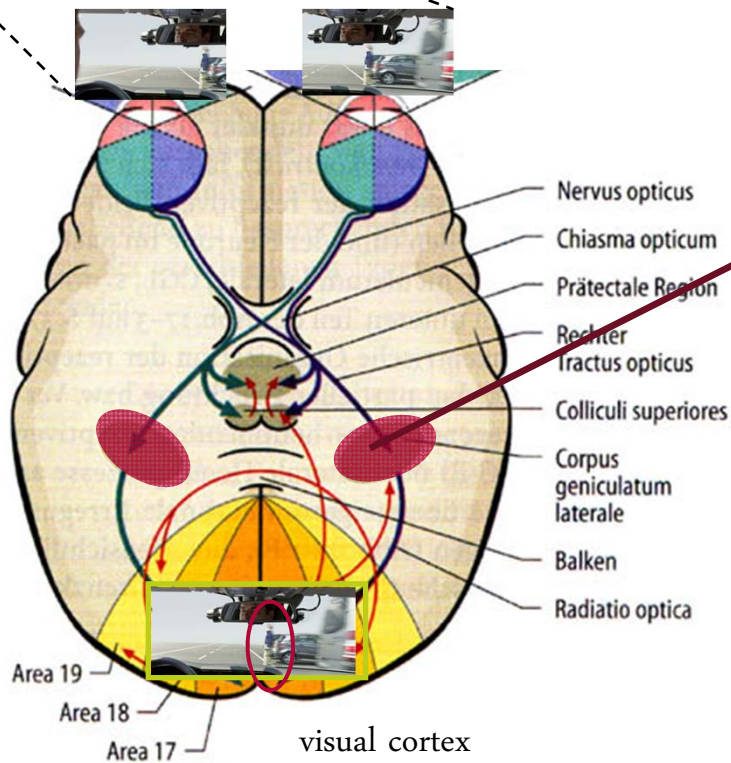
PSD: Power Spectral Density of a 15 sec EEG segment with an alpha spindle spectral peak at about 11.5 Hz and the exponential fit as a red line.

The area above the exponential curve marks the signal power and the area below the approximated noise power.

## Realizing and evaluating the driving situation

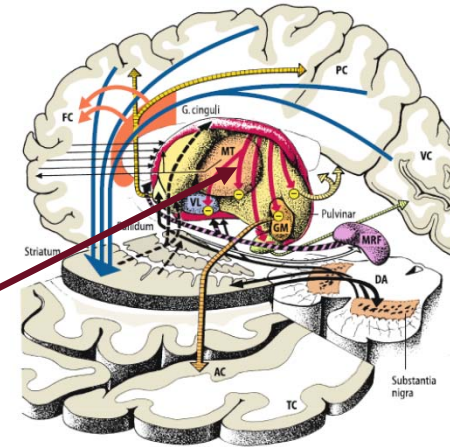


## Visual information processing



### Limited Capacity Control System

In prefrontal cortex and gyrus cinguli:  
decision which information can pass.



looked-but-failed-to-see

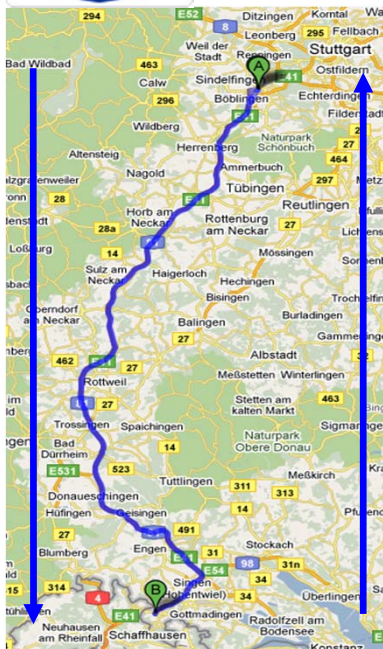
Birbaumer, N., & Schmidt, R. F. (Eds.) (2006).

*Springer-Lehrbuch. Biologische Psychologie* (6., vollst. überarb. und erg. Aufl.)

Heidelberg: Springer Medizin.

Alpha spindles are assumed to be  
influenced by this interplay between  
cortex and thalamus  
indicating the degree of  
visual information processing

## Experimental Design



40 participants, daytime

Age range: 22-58 yrs

Highway A81

Monotonous conditions

Distance: about 240 km

Driving duration: 2 h

120km/h maximum speed

(adaptive cruise control)





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1.5 min	<b>aud</b>	auditory secondary task
3 min	<b>vis</b>	visuomotor secondary task
	<b>dri</b>	driving only



## Hypothesis

Primary driving task without secondary task

> baseline



alpha spindle rate

Driving with visuomotor secondary task

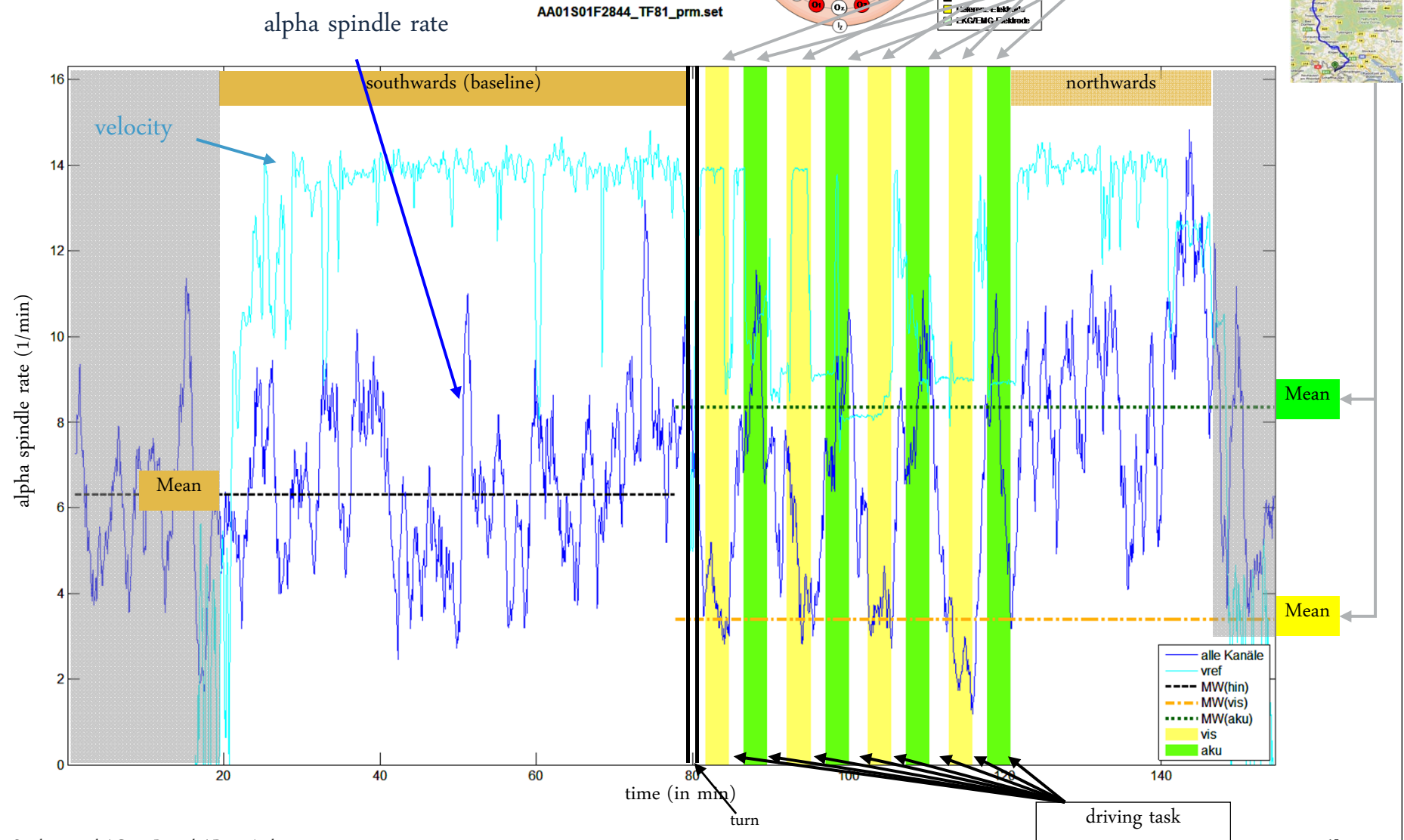
> decrease alpha spindle rate



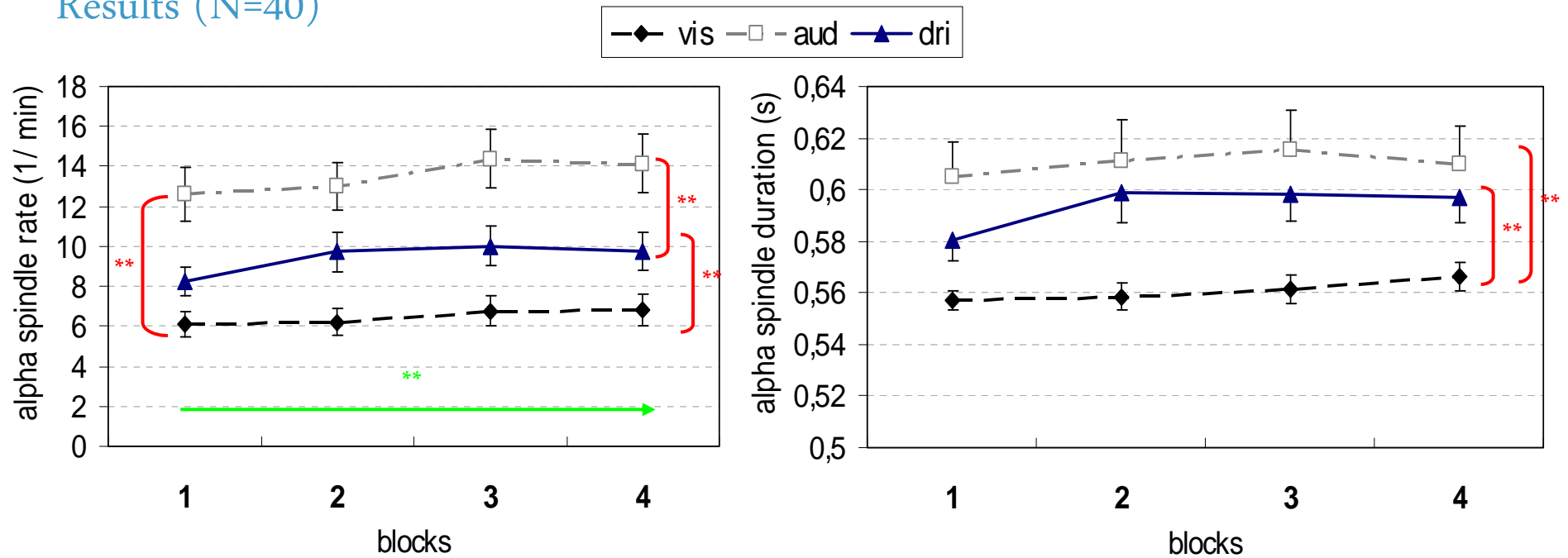
Driving with auditory secondary task

> increase alpha spindle rate





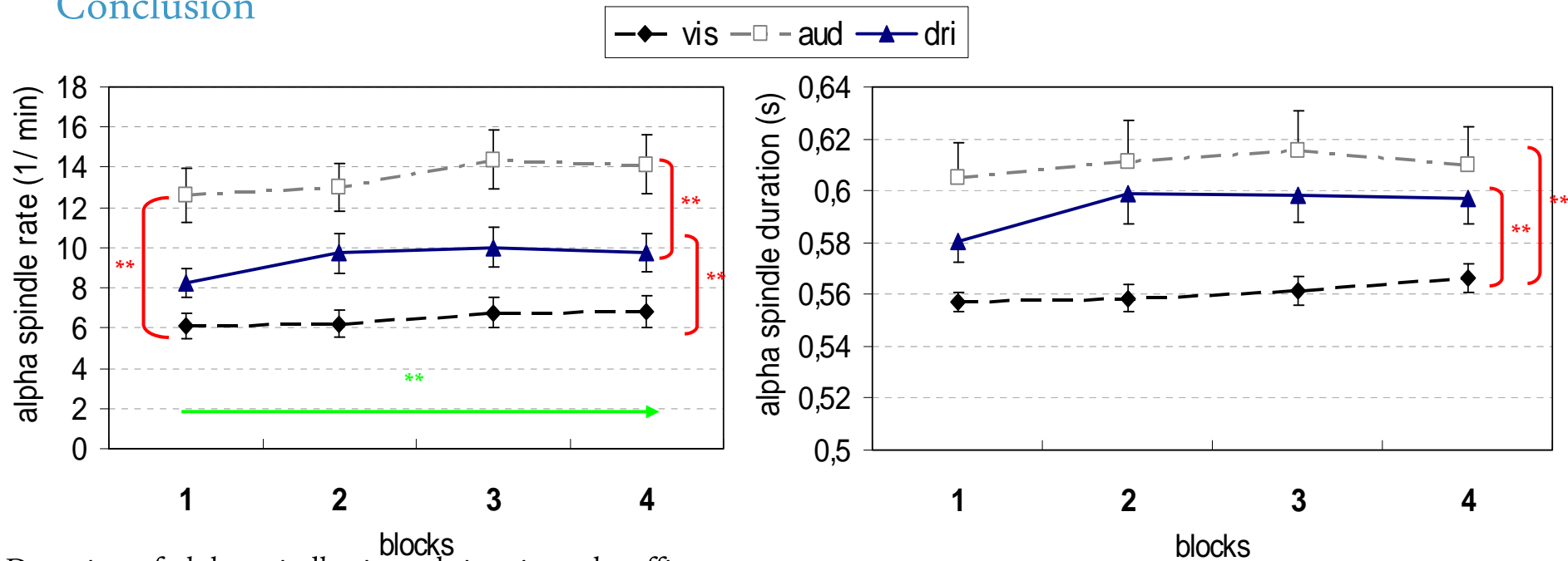
## Results (N=40)



		Main effect		
		F(3,117)	p	$\eta^2$
time-on-task	spindle rate	6.494	<.001	.143
	spindle duration	3.551	.018	.083
		F(2,78)	p	$\eta^2$
distraction	spindle rate	144.256	<.001	.787
	spindle duration	39.357	<.001	.502



## Conclusion

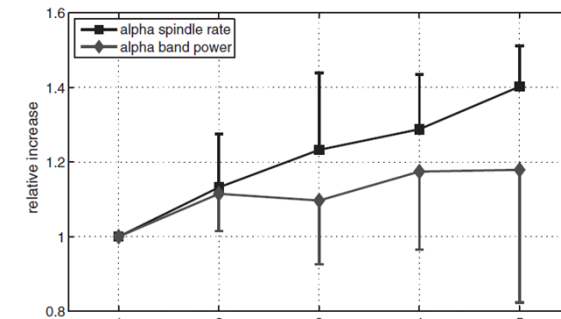


Detection of alpha spindles in real-time in real traffic

$\alpha$ -spindles represent a robust EEG-measure sensitive to visual information processing

Long-term effects on alpha spindle rate (fatigue)

Short-term variations on alpha spindle rate (attention)



M. Simon et al./Clinical Neurophysiology 122 (2011) 1168–1178