NORAH Sleep Study External Comment

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Disclaimer

- The University of Pennsylvania and the German Aerospace Center (DLR) collaborated on the NORAH project.
- ▶ I am a former employee of the German Aerospace Center (DLR).
- I am currently President of the International Commission on Biological Effects of Noise (ICBEN).
- I am a paid advisor of the World Health Organization (WHO) for the revision of the Community Noise Guidelines.
- ▶ I have otherwise no conflicts of interest to report.



Overview

- Importance of undisturbed sleep for health and wellbeing
- Brief background: Measurement of sleep
- Discussion and evaluation of NORAH sleep study
 - Advancement and deployment of simpler VMR methodology to investigate noise effects on sleep
 - Differences in findings between Cologne and Frankfurt
- Conclusions and perspectives



Functions of Sleep

- Many functions of sleep are still unknown!
- ▶ <u>BUT</u>: Sleep is *essential* (i.e., life without sleep is impossible).
 - Sleep is *ubiquitous* (i.e., everybody does it).
 - Sleep *recuperates* (i.e., daytime performance deteriorates quickly after acute total or chronic partial sleep restriction).



"If sleep does not serve an absolutely vital function, then it is the biggest mistake the evolutionary process has ever made."

Allan Rechtschaffen, University of Chicago Sleep Laboratory, Smithsonian, November 1978

Sleep is a very active mechanism:

- Brain consumes similar amounts of energy during wake and sleep.
- Protein synthesis, hormone excretion, ...
- Immune response enhanced by sleep
- Sleep increases metabolic clearance
- Memory is consolidated and stripped from emotions
- Connections between neurons are strengthened or weakened
- Gain new insights





Permanent Neuronal Loss Caused by Sleep Deprivation?

Sleep Increases Metabolic Clearance

Walker MP, Prog.BrainRes., 2010; Wagner et al., Nature, 2004, Xie et al., Science, 2013, Zhang et al., J. Neurosci., 2014

<u>Undisturbed</u> sleep of <u>sufficient length</u> is essential for cognitive performance, well-being and health.

Sleep Duration:

Adults should sleep 7 or more hours per night on a regular basis to promote optimal health.

Sleep Continuity:

Periods of uninterrupted sleep in excess of 10 min are required for sleep to be restorative.



Bonnet, Psychophysiology, 1986, 263-71 AASM/SRS consensus statement: Watson et al., SLEEP 2015, 1161-83

Signals for Sleep Stage Classification





R&K Sleep Stage Classification (30 sec epochs)



Hypnogram of Healthy Undisturbed Sleep



Awakening reaction

~ 25 per night

Duration: at least 15 sec



36 sec



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EEG-Arousal

~ 100 per night

Sleep 1992 15(2): 173-184



36 sec



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Noise and Sleep



1.6 Million healthy life years lost annually in the EU due to environmental noise



Burden of disease from environmental noise, WHO, 2011



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Differences in Sensitivity to Noise



Medicine

Restricted Generalizability of Noise-Effects Studies

- Low response rates
 (especially for polysomnography)
- Many exclusion
 criteria
 (children, elderly, diseased)
- How do the nonresponders and non-eligible react?





Polysomnography (PSG) – Pros and Cons

- Polysomnography is the gold standard for measureing sleep and the effects of noise on sleep.
- It is currently the only method that allows differentiation of sleep stages and thus a look at sleep architecture.



- However, polysomnography also has <u>several disadvantages</u>:
 - Invasive: Electrodes may influence sleep
 - Expensive: Instrumentation and data analysis by trained personnel
 - Subjective: Visual scoring of sleep stages with high inter- and intrarater variability
 - **Rigid**: Sleep stage scoring bound to 30-sec epochs
- Is it possible to get similar insights with simpler methodology while addressing some of PSG's disadvantages?





Medicine













ECG and Motility as Predictors for EEG Arousals

- ▶ <u>Pros</u>:
 - One small inexpensive device (Actigraphy and 2 electrode ECG)



- Subjects can apply and detach electrodes themselves
- ECG = robust signal \rightarrow low artifact rate
- Automatic and objective data analysis without inter- and intra-rater variabilities → increases comparability between studies
- Not bound to 30 s epochs
- Inexpensive: allows larger sample sizes at same expense
- <u>Cons</u>:
 - Focuses on sleep fragmentation, not sleep architecture
 - Cannot differentiate between wake and sleep
 - Heart rate increases during REM sleep can be misclassified





Agreement between Visual and Automatic Arousal Scoring





Penn Alg kappa results for each subject Consensus arousals (Gold Standard)

(< 0.61, 0.61-0.80, 0.81-1.00)

Subject	Карра	Subject	Карра	Subject	Карра
1	0.993	17	0.988	33	0.967
2	0.800	18	0.859	34	0.940
3	0.867	19	0.993	35	0.820
4	0.523	20	0.995	36	0.956
5	0.994	21	0.754	37	0.890
6	0.840	22	0.928	38	0.792
7	0.883	23	0.999	39	0.998
8	0.987	24	0.855	40	0.965
9	0.679	25	0.851	41	0.843
10	0.926	26	0.735	42	0.859
11	0.943	27	0.852	43	0.989
12	0.853	28	0.951	44	0.765
13	0.806	29	0.893	45	0.955
14	0.354	30	0.870	46	0.985
15	0.976	31	0.977	47	0.815
16	0.930	32	0.928	48	0.769
				49	0.928



Vergleich zwischen Polysomnografie und vegetativ-motorischer Methode



Maximalpegel, am Ohr des Schlafenden [dB(A)]





ECG-based Arousals Overestimate Awakenings Because the Mothodology is More Sensitive





Fluglärmassozierte Aufwachwahrscheinlichkeit an den Flughäfen Frankfurt und Köln-Bonn



Maximalpegel, am Ohr des Schlafenden [dB(A)]



Tiefschlafdauer





Changes in Sleep Structure (AIRORA-Study)



Conclusions and Perspectives

- The NORAH study is the largest polysomnographic study on the effects of aircraft noise on sleep ever.
- The results show no difference in total sleep time, sleep efficiency, sleep latency, or time spent awake before and after the introduction of a traffic curfew from 11 pm until 5 am (probably due to low traffic density before curfew introduction).
- Unplanned, noise-induced awakenings may nevertheless impair sleep continuity and recuperation.
- The results demonstrate high levels of sleep fragmentation in early morning hours.



Conclusions and Perspectives (2)

- Comparisons between NORAH and a study performed at Cologne/Bonn airport suggest:
 - Significantly reduced total sleep time, sleep efficiency, deep sleep and increased sleep latency and time spent awake at Cologne/Bonn airport
 - Higher awakening probabilities at the same maximum sound pressure level at Cologne/Bonn
- In-depth analyses are needed to clarify whether these differences are real and to what degree they are influenced by visual scoring:
 - Using the same visual scorer for Frankfurt and Cologne/Bonn
 - Using objective methods (ECG algorithm, power spectral analysis)



Conclusions and Perspectives (3)

- Advancing and deploying an objective, less-expensive methodology to investigate the effects of aircraft noise on sleep fragmentation constitutes a major milestone for noise-effects research.
- More studies are needed that
 - investigate even larger, representative samples
 - make comparisons between different airports and countries
- Valid exposure-response functions that can inform health impact assessments and political decision making are the ultimate goal.



Thank you for your attention!



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