Performance research on sleep, hunger and driver vigilance

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SAA Webinar 1

- Webinar 1 in May 2014 dealt with the performance of schoolwork by children
- It summarised the findings of ASHRAE 1257:

  Warmth reduces performance: -3.5%/degC

  Poor ventilation reduces performance:

  half the outdoor air supply rate = -14.5%
- Classroom windows are opened when it is warm, but not to improve the ventilation rate

SAA Webinar 2

- Webinar 2 in November 2014 dealt with thermal & air quality effects on officework
- Workrate is 8% lower at 27C (slightly warm) vs. 20C (cool) when clothed for 25C (neutral)
- Bioeffluents and emissions reduce workrate
- RH<20% affects eyes & reduces workrate
- Effects of T, pollutants & noise accumulate
- Individual choice improves performance

SAA Webinar 3

Webinar 3 deals with research on how other factors affect our performance 24/7 :

- Bedroom ventilation rate and sleep quality
- Poor sleep and next-day performance
- Breakfast and morning performance
- Lunch and afternoon performance
- Vehicle T and driver vigilance
- Airborne dust and driver vigilance

Sleep

- Bedroom ventilation is poor in Denmark:

  57% below minimum (Bekö et al. 2010)
- Bedroom ventilation is poor in Singapore due to split-cooling AC (Sekhar & Goh 2011)
- We spend more hours asleep than at work, every week, so more energy on HVAC for sleep
- ASHRAE would not fund research on bedroom ventilation – ”important but too difficult”

Strøm-Tejsen's DTU postdoc on sleep

- Two field-intervention experiments on bedroom ventilation, sleep and next-day performance were performed
- Sleep was recorded using actimeters that distinguish sleep from waking
- Subjects then marked subjective scales
- Performance was assessed next day online (DTU's Remote Performance Measurement)

Sleep experiment 1

- 7 male, 7 female subjects, two weeks
- 14 identical student rooms
- Windows open or closed for a week
- Heater thermostat kept Room Temperature at setting preferred by each subject (16-28C)
- Average T window closed: 23.9degC (54%RH)
- Average T window open: 24.7degC (40%RH)
- Women selected 3degC higher Room T

Sleep experiment 1

- Closed window average CO2 level:
  2585ppm (range 1700-3900ppm)
- Open window average CO2 level:
  660ppm (range 500-800ppm)
- Intervention was successful

Sleep experiment 1

- Sleep latency was reduced with window open
  (subjects fell asleep more rapidly: $P<0.05$)
- Increase in sleep efficiency ?
  (%time in bed asleep increased: $P<0.08$)
- Less sleepy next day? ($P<0.06$)
- Easier to concentrate next day? ($P<0.08$)
- No significant effect on next-day performance
- Noise and draft from the open window may have counteracted the positive effects of better air quality

Sleep experiment 1

Published as:

- Strøm-Tejsen P, Wargocki P, Wyon DP and Kondracka A (2014) The effect of air quality on sleep. In: Proceedings of the 13th International Conference on Indoor Air Quality and Climate: Indoor Air 2014, Hong Kong, Paper HP0506

References

- Bekö G, Lund T, Nors F, Toftum J, Clausen G (2010) Ventilation rates in the bedrooms of 500 Danish children. Building & Environment, 45, 2289-2295

- Sekhar SC, Goh SE (2011) Thermal comfort and IAQ characteristics of naturally/mechanically ventilated and air-conditioned bedrooms in a hot and humid climate. Building & Environment, 46, 1905-1916

Sleep experiment 2

- 8 male, 8 female subjects, two weeks
- 16 identical student rooms
- Extract ventilation in corridor, air inlet in wall
- CO2 was reduced in first or second week by running a fan installed in the air inlet
- Almost silent computer cooling fan (22dBA)
- Fan came on if CO2 was >900ppm
- Heater thermostat again set by each student

Sleep experiment 2

- Average room temperature was 21.9degC
- Operating the inlet fan did not change Room T
- Room T selected ranged from 14-28degC
- Women again selected 3degC higher Room T
- Average RH was 40% with the fan operating, 52% in the week with no fan

Sleep experiment 2

- Without fan average CO_2 level:

  2395ppm (range 1600-3300ppm)

- With fan average CO_2 level:

  835ppm (range 895-935ppm)

- Intervention was successful

Sleep experiment 2

- Sleep efficiency was higher with fan
  (more time in bed asleep: $P<0.05$)
- With CO_2 controlled, subjects reported:
  Feeling better ($P<0.05$)
  Feeling more rested ($P<0.05$)

Sleep experiment 2

- Subjects slept objectively better and next day reported feeling more rested
- It is then reasonable to expect them to feel less sleepy and to perform better:

  Felt less sleepy ($P<0.05$, 1-tail test)

  Worked better ($P<0.05$, 1-tail test)

  (on Baddeley test of logical thinking)

Sleep experiment 2

Published as:

- Strøm-Tejsen P, Wargocki P and Wyon DP (2014) The effect of CO2 controlled bedroom ventilation on sleep. Proceedings of RoomVent 2014, Sao Paulo, Brazil, 19-22 October 2014

Breakfast and performance

Breakfast was manipulated experimentally for:

- 81 Swedish children (4 classes, Gävle school)
- 166 Swedish children (10 classes)
  (2 classes in each of 5 Linköping schools)
- 515 Chinese children (12 classes)
  (4 classes in Guangzho, Shanghai & Beijing)
- 32 Swedish adults (Electrolux factory)

Performance was measured in each experiment

Swedish children pilot study

- 4 classes of 10-year-old children took part
- Half the parents in each class were persuaded to provide a poor breakfast on certain days
- They used our guidelines and kept logbooks
- Average nutritional values were estimated:
- Breakfast A: 507kcal, 21g protein
- Breakfast B: 197kcal, 4g protein

Swedish children pilot study

- On the day a test was applied, a given child could have eaten A or B with 50% probability
- Children did not know they were in an experiment – parents made excuses
- Teachers did not know which child had eaten which breakfast on any given day
- Test results were compared ”between-groups” combining data from all 4 classes

Swedish children pilot study

With the better breakfast (1-tail P-test):

- Arithmetic errors decreased ($P<0.05$)
- Creative thinking improved ($P<0.033$)
- Physical endurance improved ($P<0.05$)
- Logical thinking improved? ($P<0.08$, NS)
- Multiplication errors decreased? ($P<0.07$, NS)

Swedish children pilot study

Published as:

Wyon DP (1995) Two experimental studies of the effects of energy intake at breakfast on the school performance of 10-year-old Swedish children. Proceedings of the Fourth Asian Congress of Nutrition, October 7-11, Beijing, PRC: PRC Ministry of Health

Swedish children pilot study

Nutritional journals would not accept this study for publication as nutritional intake had been subjectively reported, not measured. However:

Arla was a major dairy company and publicised the findings anyway - on their milk packages

This led Swedish parents and children to regard breakfast as important for schoolwork

10-year-old Swedish children

- Swedish children now ate a good breakfast
- Two different breakfasts were prepared and delivered on Monday to each child's home
- Each breakfast box was dated
- Parents served scheduled breakfast each day
- Dietary recall by telephone for each child
- Uneaten food was boxed and returned

10-year-old Swedish children

- Breakfast A, kcal: Boys 832, Girls 567
  (cereals, milk, bread, cheese, juice, apple)
- Breakfast B, kcal: Boys 197, Girls 147
  (bread, jam, cordial)

Tuesday-Friday: ABAB or AABA in same class

Teacher was blind to breakfast each child ate

Intervention: >20% RDA vs. <10% RDA

10-year-old Swedish children

With the better breakfast (1-tail tests):

- Physical endurance improved ($P<0.01$)
- Creative thinking improved ($P<0.05$)
- Hunger sensation was reduced ($P<0.001$)
- Fewer reported feeling ”bad” ($P<0.001$)
- Fewer reported feeling ”hungry” ($P<0.001$)

10-year-old Swedish children

Uneaten food was weighed to determine intake

On the days with the poor breakfast:

- Errors decreased the more they ate
  (Addition test, $P<0.01$ boys, $P<0.05$ girls)
- Workrate increased the more the boys ate
  (Number checking, $P<0.05$)

10-year-old Swedish children

Published as:

- Wyon DP, Abrahamsson L, Järtelius M and Fletcher RJ (1997) An experimental study of the effects of energy intake at breakfast on the test performance of 10-year-old children in school. International Journal of Food Sciences and Nutrition, 48, 5-12

10-year-old Chinese children

- Chinese children rarely eat any breakfast
- Two breakfast types were served at school:

  Breakfast A: Western, >20% RDA

  (cereal, milk, bread with peanut butter)

  Breakfast B: Chinese, <10% RDA

  (Congee - rice gruel – and a steamed bun)

Guangzhou: 162 children

With the better breakfast:

- Addition workrate 16% faster ($P<0.01$)
- Multiplication workrate 16% faster ($P<0.0101$)
- Creative thinking

  C-score originality 18% higher ($P<0.05$)

  Repeated answers 17% fewer (($P<0.05$)
- Physical endurance improved ($P<0.01$, 1-tail)

Shanghai: 202 children

With the better breakfast:

- Addition workrate 12% faster ($P<0.01$)
- Multiplication workrate 13% faster ($P<0.02$)
- Logical thinking accuracy 8% better ($P<0.02$)
- Number checking workrate 9% faster ($P<0.02$)
- Physical endurance improved ($P<0.001$, 1-tail)

Beijing: 151 children

- No significant effects of breakfast shown
- Researchers reported that substantial amounts of Breakfast A were left uneaten
- The BJ children were unfamiliar with Western breakfast items and did not like them
- The intervention did not succeed

10-year-old Chinese children

Summary report to the Kellogg Foundation:

- Ma Guangsheng, Hu Xiaoqi, Gao Shujun (1998) Breakfast and school performance. Institute of Nutrition and Food Hygiene, Chinese Academy of Preventive Medicine, 29 Nan Wei Road, Beijing, China 100050.

Corresponding author: mgs@public.bta.net.cn

Electrolux factory workers

- 22 workers on a vacuum cleaner assembly line
- Came to work 15 min early for 4 weeks
- Factory served 4 different free breakfasts
- ”Market survey” of what they were worth
- Weeks 1 & 4: only good breakfasts
- Weeks 2 & 3: good and bad alternated
- Within-subjects comparison of productivity

Electrolux factory workers

Breakfast Type A: 590kcal, 20g protein
(cereals, milk, bread, butter, cheese, juice, fruit)

Breakfast Type B: 350kcal, 4g protein
(Toast with jam or pastries, cordial)

Number of units OK & Rejected were recorded each day for each worker and work-period

Electrolux factory workers

In 1st 2-hour period after breakfast:

- No effect of breakfast type

In 2nd 2-hour period with the better breakfast:

- Workrate was 6-12% better
- Fewer units were rejected
- In W1, with a good breakfast every day, workrate increased day to day (+30%)
- Workrate W4 > W1 (Hawthorne effect?)

Electrolux factory workers

These results were never published

Lunch & afternoon performance

- 111 students and teachers were recruited
- Workperiod 12.00-15.00 one Saturday
- All to work in same big hall as in examinations
- Lunch ”would be provided” 11.00-12.00
- 50% randomised to eat a cafeteria lunch
- 50% were given 2 vouchers to use later but ate a snack (coffee and a Snickers bar)

Lunch & afternoon performance

Nutritional values:

Lunch: 633kcal, 34g protein, 15g fat

(spaghetti bolognaise, salad, coarse bread, medium-fat milk)

Snack: 299kcal, 8g protein, 13g fat

(chocolate bar with toffee & peanuts, black coffee)

Those eating the snack were told there was a 3rd group eating nothing (this was not true)

Lunch & afternoon performance

- Subjects were told that some people believe they work better when hungry, some do not
- Subjects were paid a generous SEK 300 plus a bonus amount for each correct answer - they could earn up to SEK 200 more
- Each luncheon voucher was worth SEK 25
- Payment was immediate, in cash, bonus amounts were paid after the data analysis

Lunch & afternoon performance

Subjects marked Visual-Analogue scales after

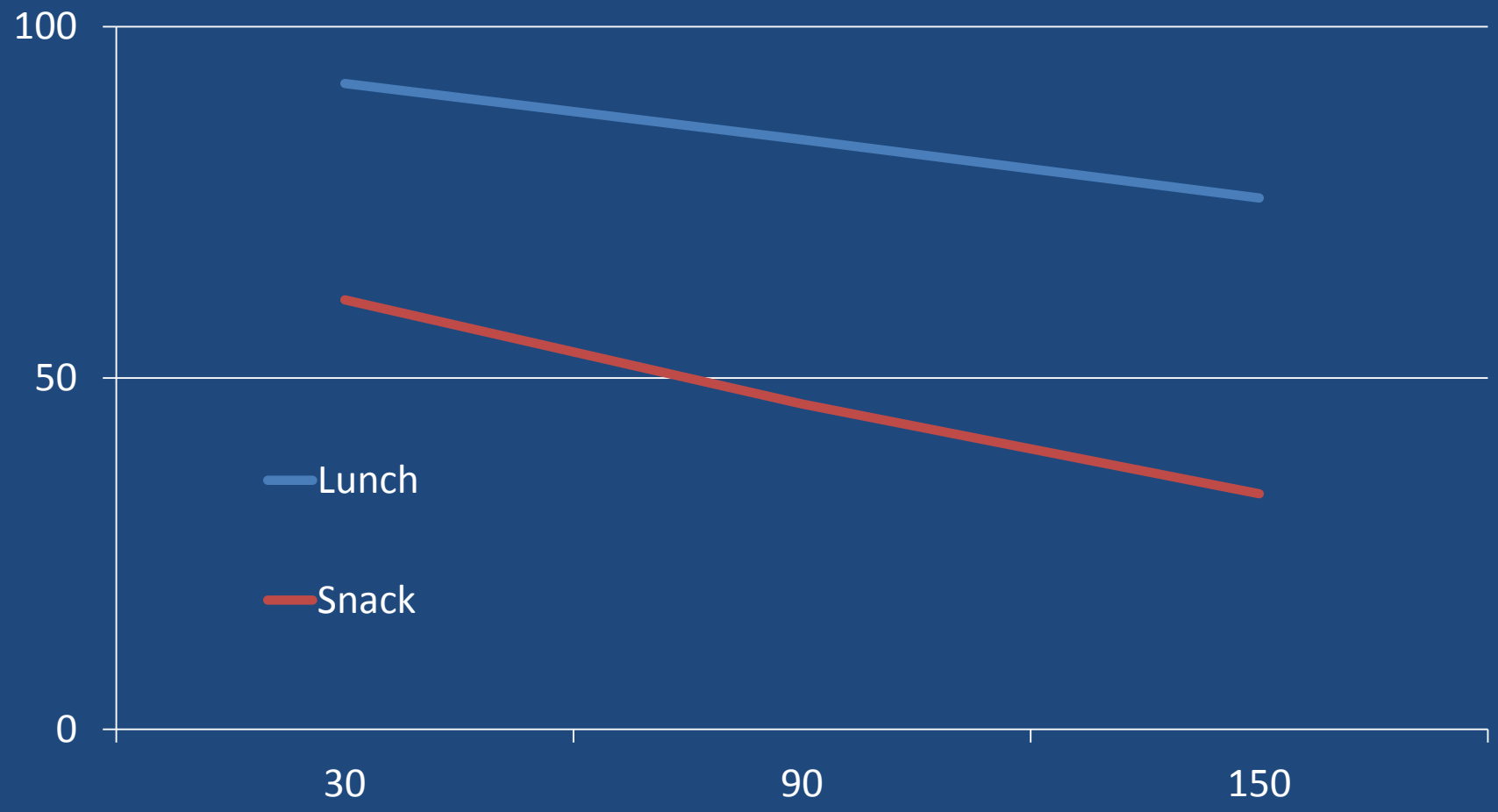
30, 90 and 150 minutes

The snack instead of lunch made people feel:

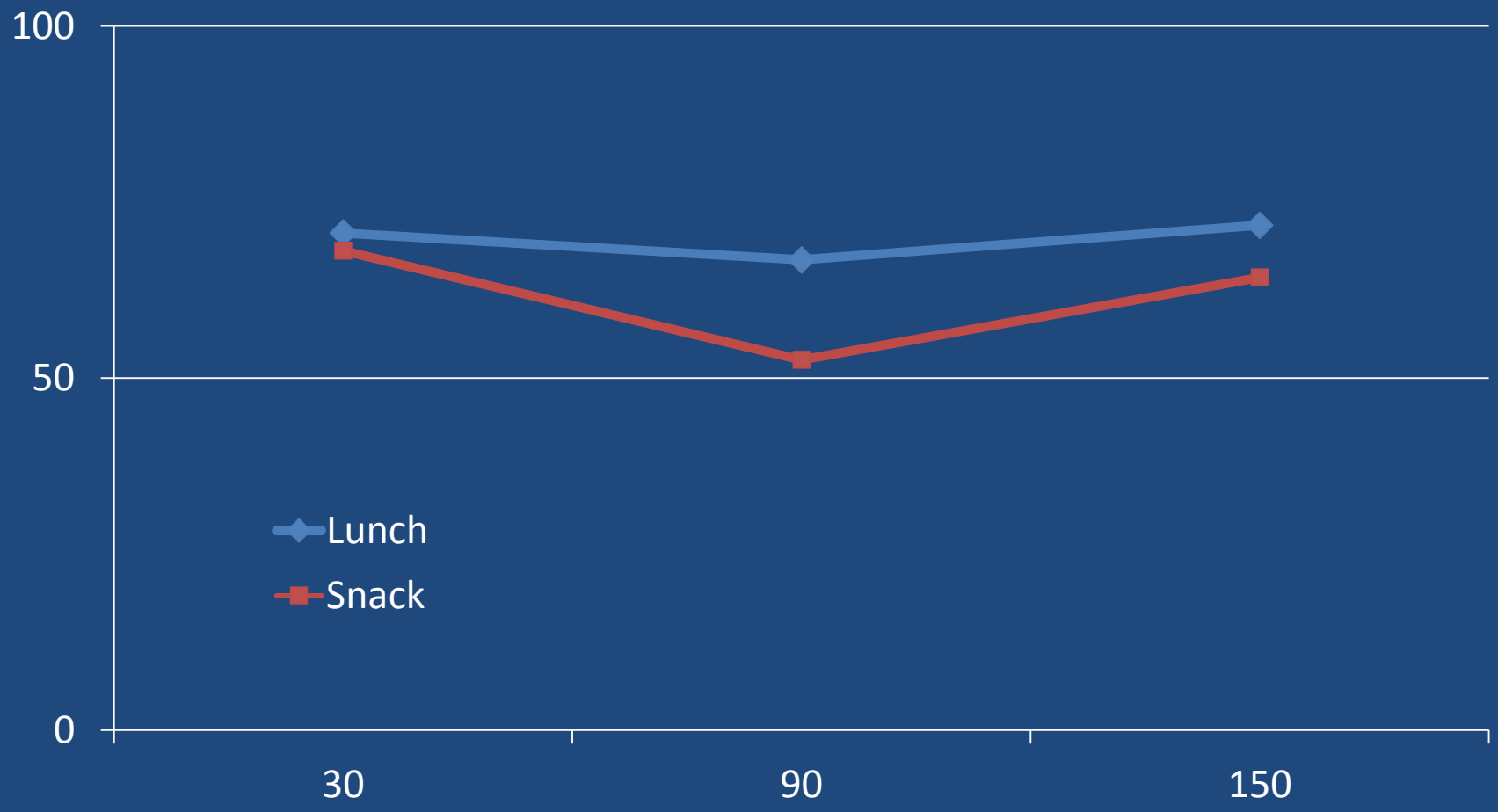
- More hungry throughout ($P<0.001$)
- Worse at 90min ($P<0.01$) only
- Less concentrated at 90min ($P<0.02$)

After 150min only hunger was worse

Hunger intensity scale (0 = very hungry, 100 = very full)



Feeling good/bad scale (100 = very good, 0 = very bad



Lunch & afternoon performance

- All subjects remained in the ”feeling good” half of the scale all afternoon, though they felt worse at 90min after a snack than after lunch
- After a snack subjects crossed into the hungry half of the scale after 1 hour and 16 minutes
- After the cafeteria lunch this would not have occurred until after 5 hours and 39 minutes
- Most of us can relate to these findings

Lunch & afternoon performance

- It was expected that a snack would maintain performance for 30 - 60 min
- It was also expected that a good lunch might actually decrease performance at first
- In fact, those eating a cafeteria lunch instead of a snack always worked better than those eating a snack, i.e. both initially and throughout the rest of the afternoon

Lunch & afternoon performance

Published in Swedish as a report to LUI (Sweden's Agricultural Research Intitute):

- Wyon DP (1989) Lunch-försöket vid Gävle Högskola: ett uppdrag från LUI (Lantbrukets Utrednings Institut).

Uppdragsgivare/reference: Jan-Olof Bengtsson

Heat & driver vigilance

- Volvo is known for passive safety engineering
- Deformation zones & seat belts protect us in the milliseconds following an impact
- Impacts occur when drivers make mistakes of observation or judgment
- Failure to observe & respond to peripheral signals is the cause of most impacts
- Driver vigilance is thus crucial for road safety

Heat & driver vigilance

- Most studies of driver vigilance are really tests of response time, e.g. to pedestrians, elks
- These stimuli are clear and expected
- Driver vigilance includes detecting signals that are initially peripheral and unclear
- Drivers must distribute their attention optimally to detect such signals
- Distribution of attention is critical

Heat & driver vigilance

- Most”vigilance” studies are in simulators
- Subjects can redistribute attention to expected signals without risking their lives
- Realistic studies must be in real traffic so drivers must concentrate on driving
- Signals should be unrehearsed, undefined
- Drivers should always be aware of anything that could happen inside or outside the car

Heat & driver vigilance

- High levels of heat stress & noise have been shown to narrow the distribution of attention
- Thermal discomfort distracts attention
- Sunshine, seat insulation & airvents, in that order, cause great thermal asymmetry in cars
- Thermal asymmetry causes local cold discomfort so drivers turn up the heat
- Warmth = drowsiness = reduced vigilance

Heat & driver vigilance

- Thermal manikins allowed Volvo to optimise the thermal environment in their vehicles
- Driver vigilance studies were then suggested to complement passive safety engineering
- Volvo Car Corporation sponsored two field studies in a moving vehicle
- A test car was constructed for these studies

Heat & driver vigilance

- 21 possible signals could occur at random
- All were such that drivers should respond, e.g. signal lights, instrument error, motor or wheel vibration, unintended operation of wipers, blinkers, horn, blue flash in a rearview mirror
- Drivers pressed a foot-pedal and reported verbally what they thought they had seen
- Response time and errors were thus available

Heat & driver vigilance

- Two conditions: Air T set to 21 or 27C
- Each subject drove for one hour
- 4 circuits of a learned route, urban+rural
- Observer noted route-finding errors
- Subjects were professional drivers + wives
- 51 male subjects, 32 female were recruited
- Each subject experienced only one condition

Heat & driver vigilance

Overthe whole 60min period:
50% more signals were missed at 27C ($P<0.013$)
RT increased by 22% at 27C ($P<0.03$)

In the second 30 minutes:
92% more signals were missed at 27C ($P<0.01$)
RT increased by 30% at 27C ($P<0.05$)

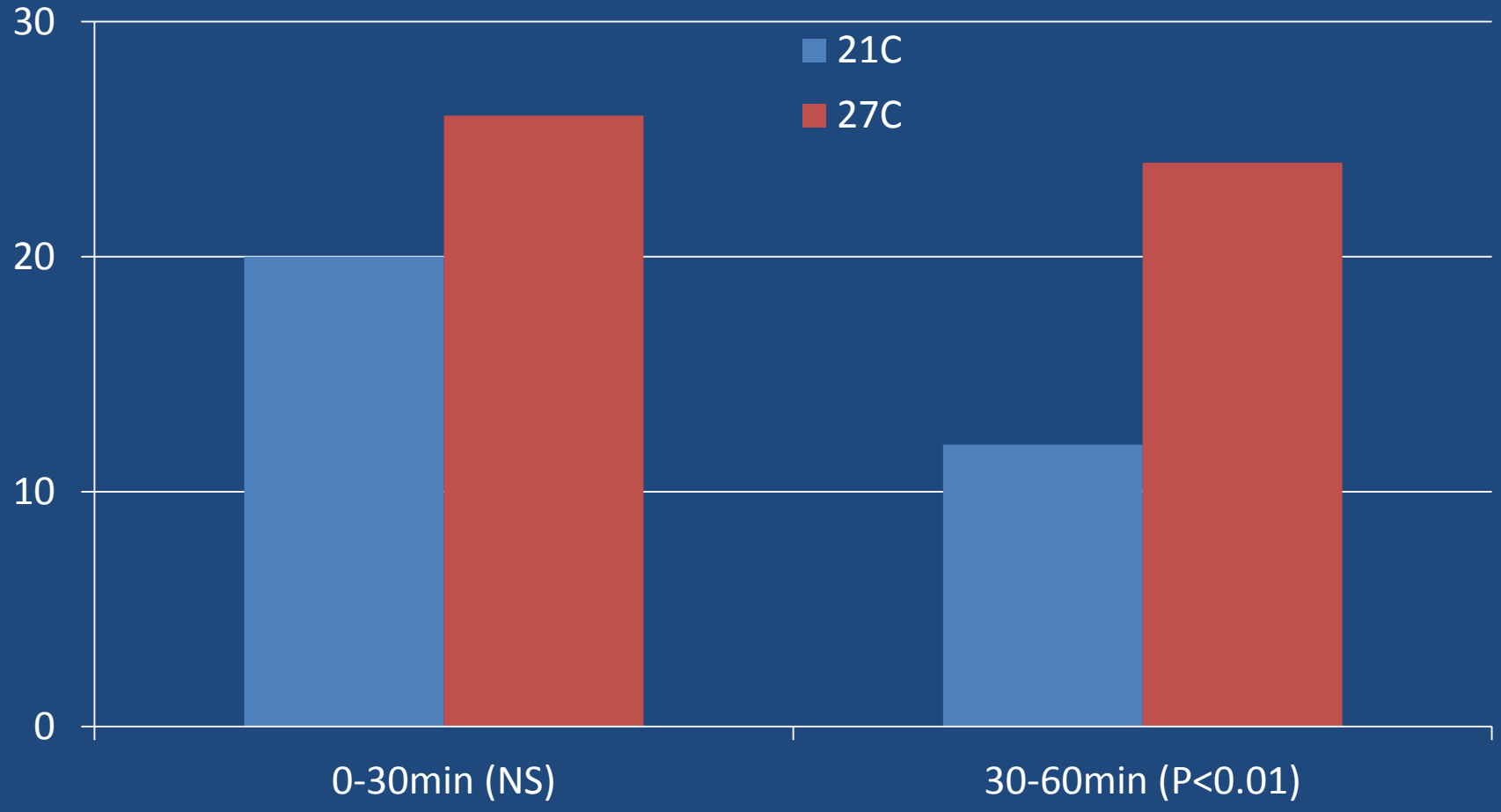
At speeds below 60km/h:
75% more signals were missed at 27C ($P<0.01$)

Heat & driver vigilance

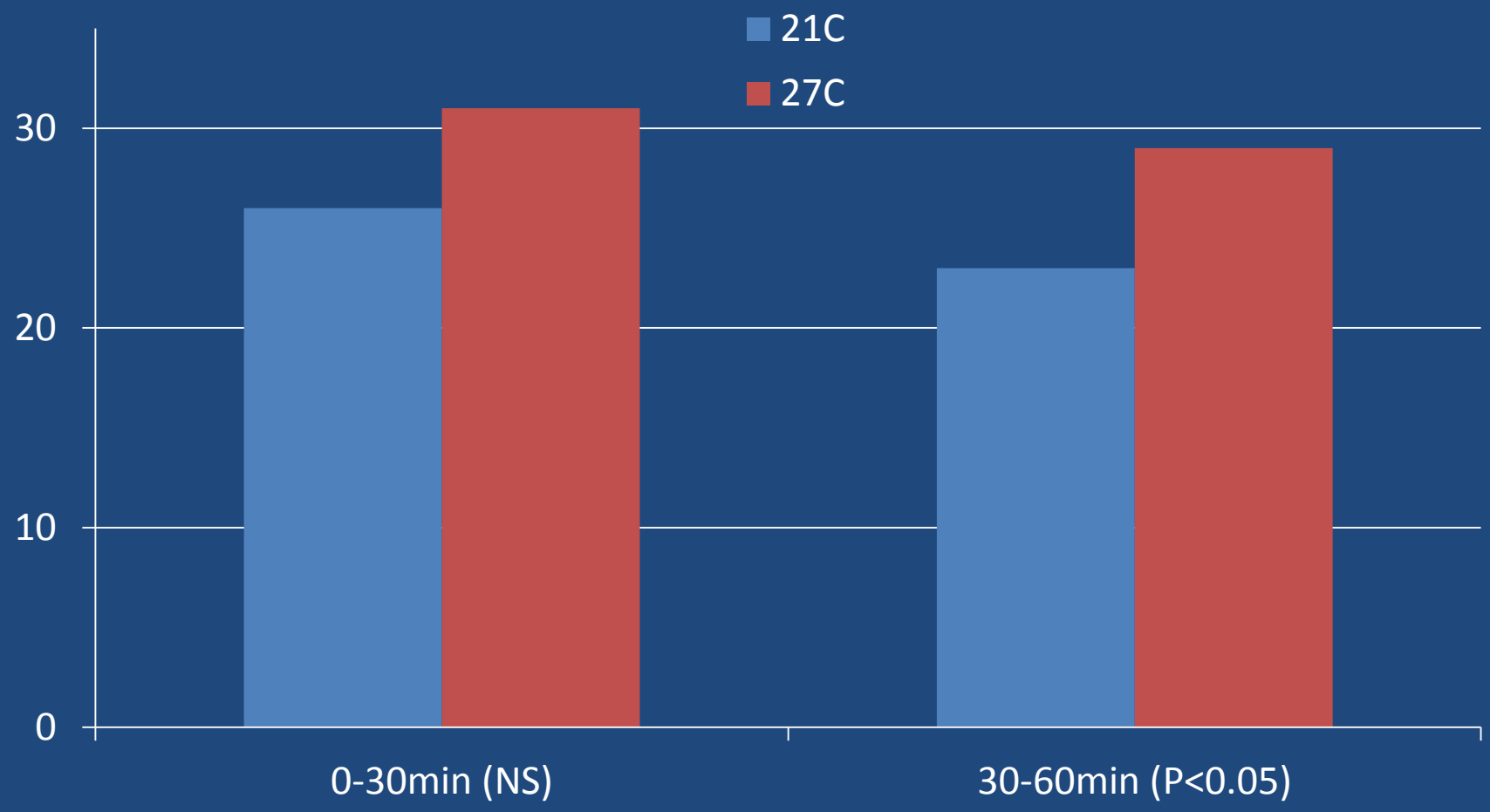
Vigilance was more affected by warmth :

- In the second half-hour
- In city traffic
- Among younger drivers (<40)
- Among male drivers

%signals missed (all subjects)



RT in seconds (all subjects)



Heat & driver vigilance

- At 60km/h, a warm vehicle travels 88m further than one with AC before a signal is detected

- In a warm vehicle, signals are undetected over 3km on 50% more occasions than with AC

This has to affect road safety

Heat & driver vigilance

Published as:

- Wyon DP, Wyon I, Norin F (1996) Effects of moderate heat stress on driver vigilance in a moving vehicle. Ergonomics, 39, 61-75

Airborne dust & driver vigilance

- Airborne dust causes eye irritation
- Eye discomfort distracts attention
- Blinking slows visual data acquisition
- Airborne dust might affect driver vigilance
- Same vehicle was used, with same approach
- Same 4 circuits, part urban, part rural
- 100 drivers (53 male, 47 female)

Airborne dust & driver vigilance

- A covert ioniser was either on or off
- 20-30 000 negative ions/ml present (or not)
- Charged particles adhere to surfaces
- Air was cleaner when ionised, BUT:
- Particles on surfaces must be cleaned off
- Filters of various kinds are to be preferred

Airborne dust & driver vigilance

For males, ioniser reduced symptoms of:

- Headache ($P<0.05$)
- Feeling bad ($P<0.05$)
- Eyes smarting? ($P<0.06$)
- Feeling giddy? ($P<0.06$)

For females, ioniser INCREASED symptoms of:

- Headache ($P<0.02$)
- Feeling bad? ($P<0.06$)

Airborne dust & driver vigilance

For the <40years, ioniser reduced symptoms of:

- Eyes feeling dry ($P<0.05$)
- Eyes smarting ($P<0.001$)
- Eyes aching ($P<0.005$)
- Eyes feeling gritty ($P<0.05$)

Airborne dust & driver vigilance

Overall, ionisation increased vigilance for:

All warning lights ($P<0.02$)

Generator failure ($P<0.005$)

Parking brake set ($P<0.05$)

RPM shown too high? ($P<0.06$)

Airborne dust & driver vigilance

For <40years, ionisation increased vigilance for:

- All warning lights (P<0.001)
- Police lights behind (P<0.02)
- Brake failure light (P<0.0.01)
- Parking brake set (P<0.0.02)
- Engine overheating (P<0.05)
- Clock running fast (P<0.05)

Airborne dust & driver vigilance

Ionisation effects were most marked :

- In the second half-hour
- For subjects <40-years-old
- For female subjects

Ionisation reduced vigilance for only one signal (speed below true speed). As this is illegal, the possibility may have been discounted

Airborne dust & driver vigilance

Conclusions:

- Fine particles irritate the eyes & considerably reduce driver vigilance

- Cabin air cleaners would increase road safety but air ionisation is not a viable solution

Airborne dust & driver vigilance

- Published as:
- Wyon DP, Wyon I, Norin F (1995) The effects of negative ionisation on subjective symptom intensity and driver vigilance in a moving vehicle. Indoor Air, 5, 179-188

THE END

The main purpose of this lecture was to show that performance can be used as a dependent variable if experiments are properly designed

A secondary purpose was to demonstrate that the conditions we experience every day have quite large effects on performance. The indoor environment has a particularly large effect