KATHOLIEKE UNIVERSITEIT
LEUVEN

The Psychophysiology of Breathing

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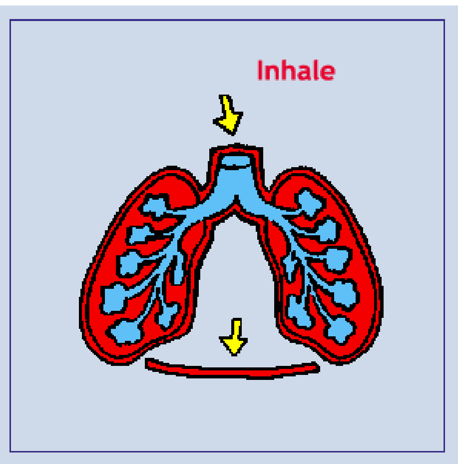
Content

- What is breathing?
- How to measure it?
- How to manipulate and study it?
- Respiratory psychophysiology : some examples

What is breathing?

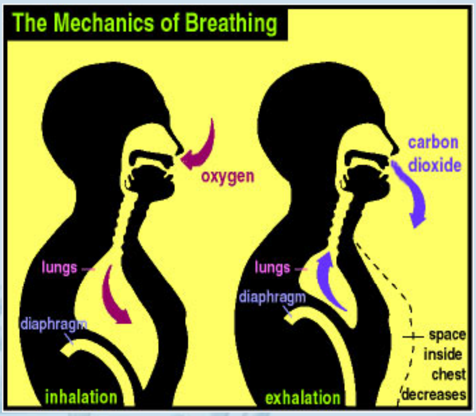
RESPIRATORY PHYSIOLOGY

Breathing…



- Biggest oscillator in the body
- Double control system
  - Voluntarily
  - Autonomically
- Relatively little investigated in psychophysiology
  - No “pure” (unsuspect) psychophysiological measure
  - Difficult to measure without altering it

Breathing…



To keep blood gas levels within (pre-set) boundaries

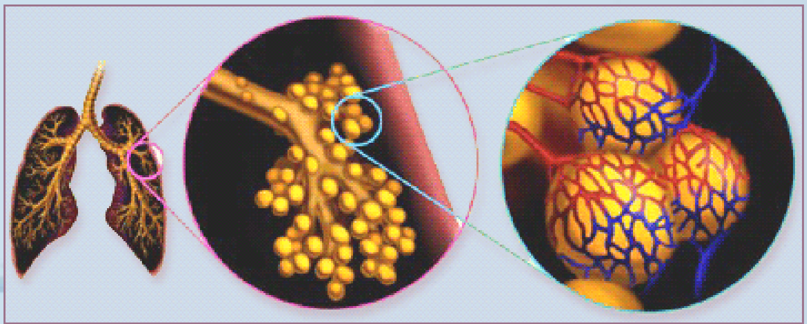
O2

- Arterial O2 saturation (SpO_2)
- 93 – 100 % Hb fully saturated by O2

CO2

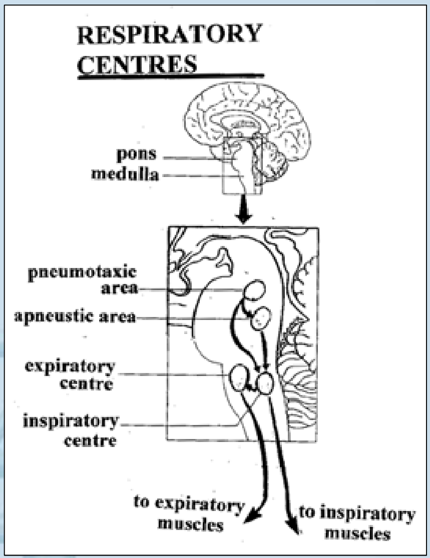
- Alveolar PCO_2 ($PACO_2$)
- Arterial PCO_2 ($PaCO_2$)
- End-tidal $P_{ET}CO_2$ (mmHg) or $F_{ET}CO_2$ (%).
- Normal $PETCO_2$ ± 40 mmHg
- Normal $F_{ET}CO_2$ (%) = ± 4.8 à 5%

Gas exchange in alveoli



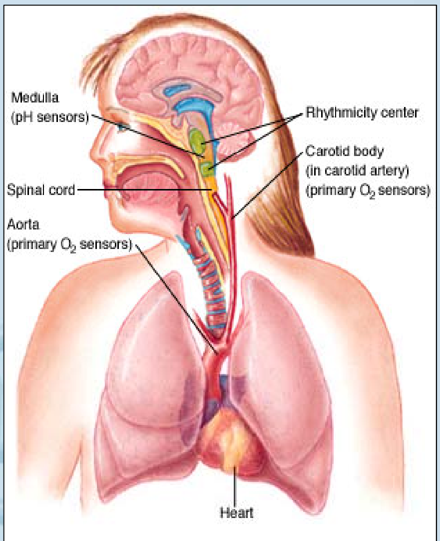
- 300 million alveoli (0.05 to 0.25 mm each)
- ±100 m² surface in contact with the outside air
- Inspired air = 21% O2 - 0 to 0.5% CO2
- Expired air = 16,5% O2 - ±5% CO2

Respiratory control



- Rhythmicity center of the medulla (brain-stem)
  - I neurons
  - E neurons
- Apneustic center (pons)
  - stimulate I neurons
- Pneumotaxic center
  - inhibits apneustic center
  - inhibits inspiration

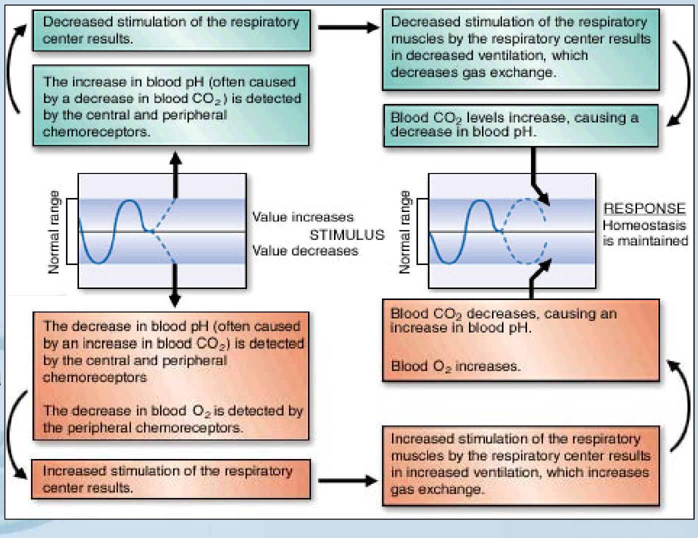
Respiratory control



- Sensors in different places in the body monitor breathing behavior and gas exchange
- Mammals are most sensitive to CO2 levels
  - varies most in respiration in response to different metabolic and environmental conditions.

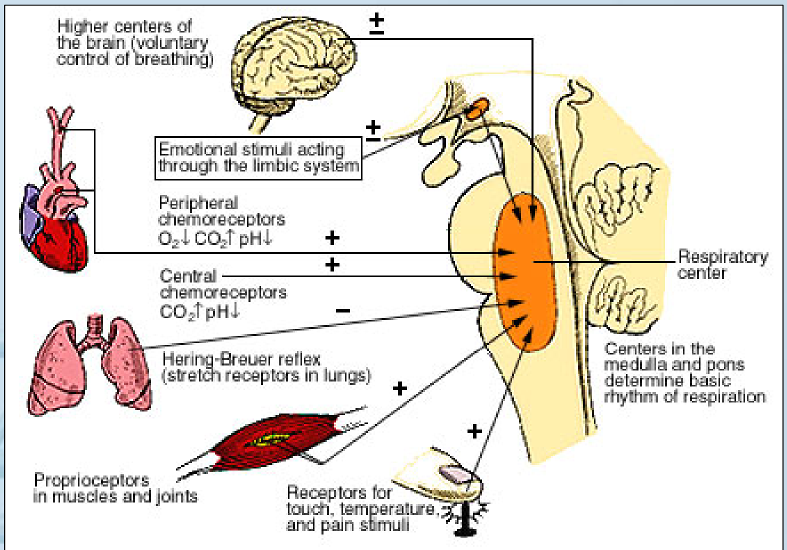
Feedback system

Hypocapnia
Cfr. HV



Hypercapnia

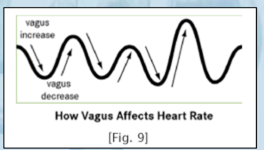
Respiratory control

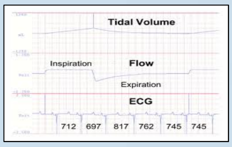


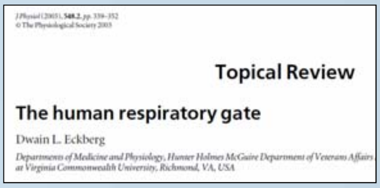
Important effects of respiration on other systems

Respiratory gating (Eckberg, 2003)

- More parasympathetic outflow during expiration than during inspiration
  - RSA : Respiratory sinus arrythmia
    - HR increases during inhalation and decreases during exhalation
      - Also other cardiorespiratory interactions
    - Fierce debate on HRV : What it means and yes/no correction for respiratory variables?
  - Startle response modulation ?
  - ??






J Physiol (2003), 548.2, pp. 339–352
© The Physiological Society 2003

Topical Review

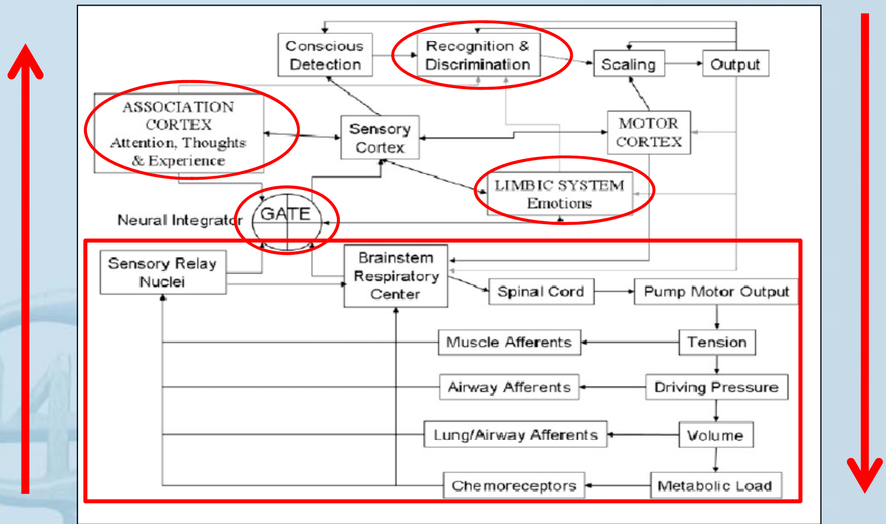
The human respiratory gate

Dwain L. Eckberg

Departments of Medicine and Physiology, Hunter Holmes McGuire Department of Veterans Affairs at Virginia Commonwealth University, Richmond, VA, USA

Respiratory sensation

Bottom-up AND top-down processes

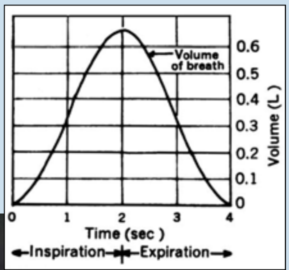


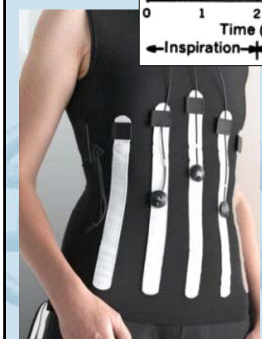
Davenport , P. in: O'Donnell et al. (2007). *Proc Am Thorac Soc*, 4, 145-168

How to measure breathing ?

MEASURES AND PARAMETERS

Time related





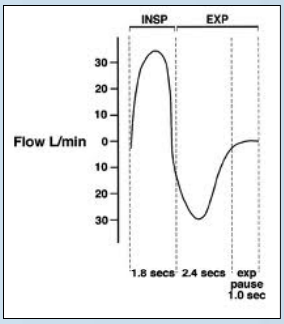
- Respiratory band (chest)
- Straps
- Termistors (nose)
- ….

- Ti : inspiratory time (s) (1,5-2 s)
- Te : expiratory time (s)
- Pauses (Pinexp – Pexpin)

- f = 60/(Ti+Te)   (10-12 br/min)
- Ti/T_{TOT} : duty cycle time
  - Reflects activity of respiratory rhythmic controller

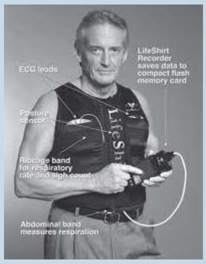
Volume related

pneumotachograph



V_T = tidal volume

500-600 ml



RIP : respiratory inductive plethysmography

Time x Volume

- $V_E = f \times V_T$ (minute ventilation, L/min; normaal ±6 L/min)
- Inspiratory drive : V_T/Ti
- …

Pressure parameters

- P100 : inspiratory occlusion pressure 100 ms after the onset of an inspiratory effort against a closed airway
  - reflects the summed motor output of the central respiratory controller (or the ‘‘central respiratory drive’’)

Central respiratory drive

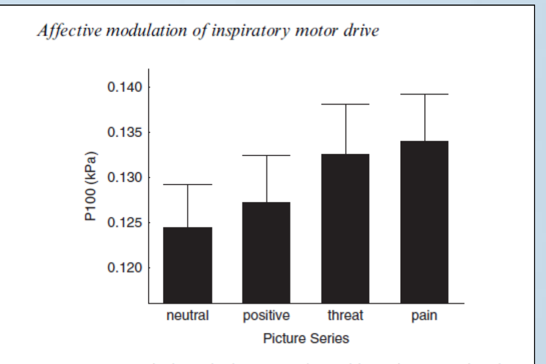
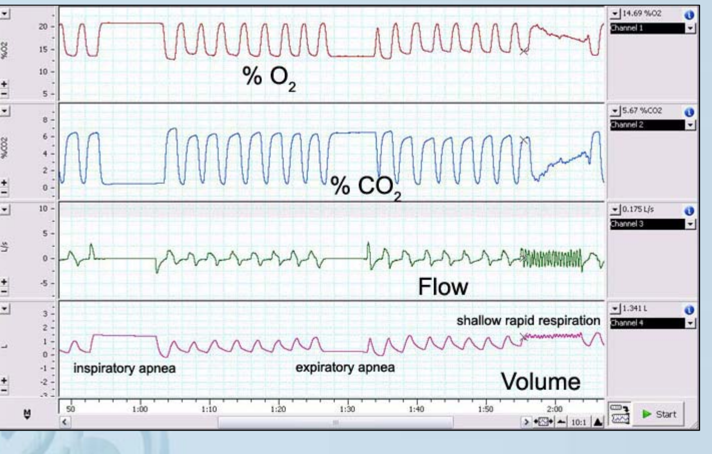


Figure 1. P100 during viewing neutral, positive, threat, and pain pictures. Vertical bars denote ± standard errors.

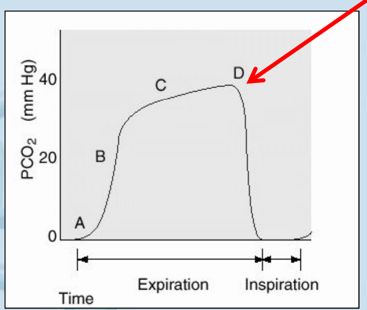
Van Diest et al., 2009

Breathing patterns



- Respiratory variability
- Sighs

Gas exchange - capnopgraphy



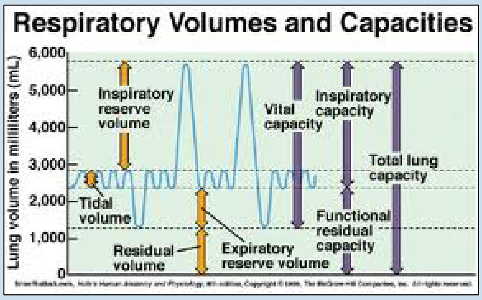
CO_2

- PetCO2 (mmHg)
  FetCO2 (%)

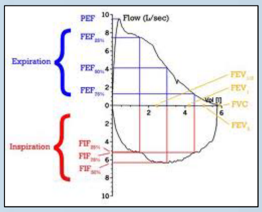
O_2

- PO_2
- SaO_2
  Photosensitive plethysmography

Clinical variables



- Flow-volume loop
- FVC
- FEV1
- PEF
- …



- Airway resistance
  - FOT : Forced oscillation technique

MANIPULATIONS IN THE LAB

Dyspneic Stimuli: CO_2-inhalation



CO_2-inhalation (5% - 7.5% - 10%)

- Chemoreceptors (pH/CO2)
- Rise in ventilation, HR, BP
- Breathlessness - air hunger
- Dizziness, warmth

35% → Panic !!

Dyspneic Stimuli: respiratory load

Flow resistors (loads)

- Mechanoreceptors
- Breathing muscles work harder
- Breathlessness – effort
- Fatigue

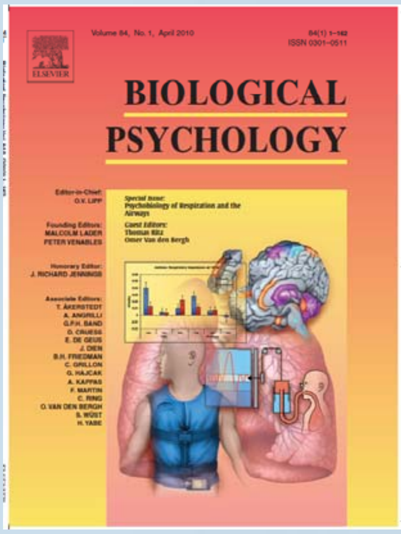
Other

- Occlusions
- Breath holding

RESPIRATORY PSYCHO(PHYSIO)LOGY

Special Issue Biological Psychology

Ritz, T., & Van den Bergh, O. (2010).
Psychobiology of respiration and the airways.
Biological Psychology, 84(1).



Editorial

Reviews

Original Research

(Contents continued on page 162)

M. Pappens, O. Van den Bergh, S. De Peuter, J. Bresseleers, D. Vansteenwegen, I. Van Diest, Defense reactions to interoceptive threats: A comparison between loaded breathing and aversive picture viewing 98

J. Blechert, F.H. Wilhelm, A.E. Meuret, E.M. Wilhelm, W.T. Roth, Respiratory, autonomic, and experiential responses to repeated inhalations of 20% CO_2 enriched air in panic disorder, social phobia, and healthy controls 104

D. Rosenfield, E. Zhou, F.H. Wilhelm, A. Conrad, W.T. Roth, A.E. Meuret, Change point analysis for longitudinal physiological data: Detection of cardio-respiratory changes preceding panic attacks 112

P. Grossman, F.H. Wilhelm, M. Brutsche, Accuracy of ventilatory measurement employing ambulatory inductive plethysmography during tasks of everyday life 121

A. von Leupoldt, K. Taube, M. Henkhus, B. Dahme, H. Magnussen, The impact of affective states on the perception of dyspnea in patients with chronic obstructive pulmonary disease 129

S.J. Kopel, N. Walders-Abramson, E.L. McQuaid, R. Seifer, D. Koinis-Mitchell, R.B. Klein, M.Z. Wamboldt, G.K. Fritz, Asthma symptom perception and obesity in children 135

N.D. Giardino, J.L. Curtis, J.L. Abelson, A.P. King, B. Pamp, I. Liberzon, F.J. Martinez, The impact of panic disorder on interoception and dyspnea reports in chronic obstructive pulmonary disease 142

S. Alexander-Miller, P.W. Davenport, Perception of multiple-breath inspiratory resistive loads in males and females 147

B. Gavish, Device-guided breathing in the home setting: Technology, performance and clinical outcomes 150

M.K. Karavidas, P.M. Lehrer, S.-E. Lu, E. Vaschillo, B. Vaschillo, A. Cheng, The effects of workload on respiratory variables in simulated flight: A preliminary study 157

T. Ritz, O. Van den Bergh, In Memoriam Michael D. Goldman, M.D. 161

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Dyspnea perception => symptom perception

- Perceptual-cognitive processes
- Affective-motivational responses
- Clinical implications (asthma, COPD)

Emotion and breathing regulation

- Breathing during defensive response mobilization
- Why do you sigh?
- Feedforward-regulation of breathing
- Interoceptive fear conditioning to respiratory cues
- Breathing and relaxation

Research Group on Health Psychology - Leuven

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THE PLASTICITY OF SELF-REPORTED SYMPTOMS

Dyspnea as a Multidimensional Experience

Dyspnea/breathlessness…

„… a **subjective experience** of breathing discomfort that consists of **qualitatively distinct sensations and affective-motivational responses** that vary in intensity

„… experience derives from interactions among multiple physiological, **psychological**, **social**, and environmental factors...“

American Thoracic Society (1999). *American Journal of Respiratory and Critical Care Medicine,* 159, 321-340

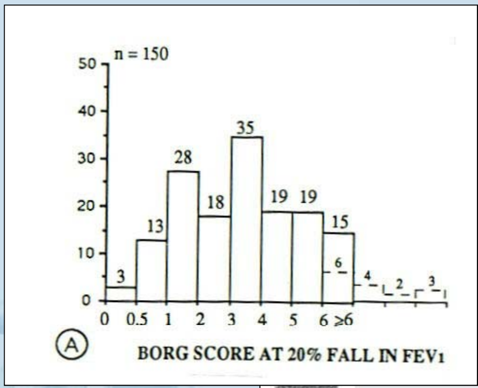
Dyspnea - breathlessness

Distinct Sensations

- Air hunger – suffocation
  - Mismatch ventilatory drive – actual ventilation
- Effort - work of breathing
  - Respiratory muscles must work harder
- Chest tightness
  - Bronchoconstriction

Simon et al. (1990). *American Review of Respiratory Disease*, 142,1009-1014
Banzett & Moosavi, APS Bulletin, 11, 2001

Large individual differences



Clinical Psychology Review 29 (2009) 317–327

Contents lists available at ScienceDirect

Clinical Psychology Review

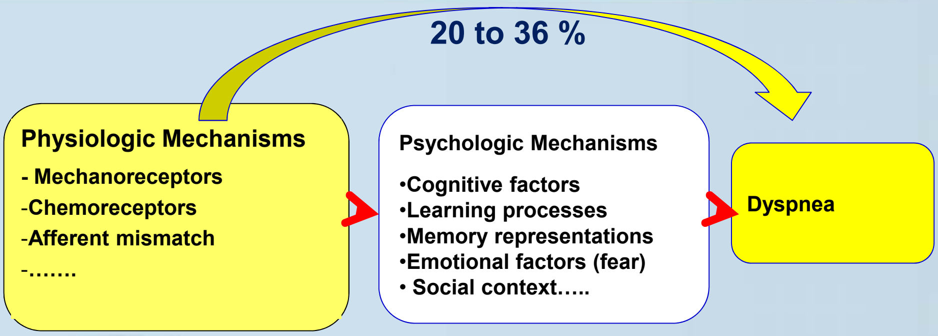
ELSEVIER

Inaccurate perception of asthma symptoms: A cognitive–affective framework and implications for asthma treatment

Thomas Janssens [a], Geert Verleden [b], Steven De Peuter [a], Ilse Van Diest [a], Omer Van den Bergh [a,*]

[a] Research group on Health Psychology, Department of Psychology, University of Leuven, Belgium
[b] Department of Respiratory Medicine, University Hospital Gasthuisberg, Leuven, Belgium

Treating Dyspnea



- 3rd major complaint in medicine
  - after fatigue and pain
  - (cardio)pulmonary disorders
  - neuromuscular
  - 70% of terminal cancer patients
- % explained by either set varies
  - among persons
  - as a function of time/learning experiences within person

Top-down processes

- Perceptual-cognitive factors
  - Attention
  - Interpretation (“catastrophizing”)
  - Expectancies/learning
  - Memory
- Emotional factors
  - Fear
  - Controllability
- Social context…

Health Psychology
2008, Vol. 27, No. 1, 93–99

0278-6133/08/$12.00 DOI: 10.1037/0278-6133.27.1.93

Illness-Specific Catastrophic Thinking and Overperception in Asthma

Steven De Peuter
Research Group Health Psychology

Valentine Lemaigre
University Hospital Gasthuisberg

Ilse Van Diest and Omer Van den Bergh
Research Group Health Psychology

Acquiring bodily symptoms

Odor-CO_2 inhalation paradigm

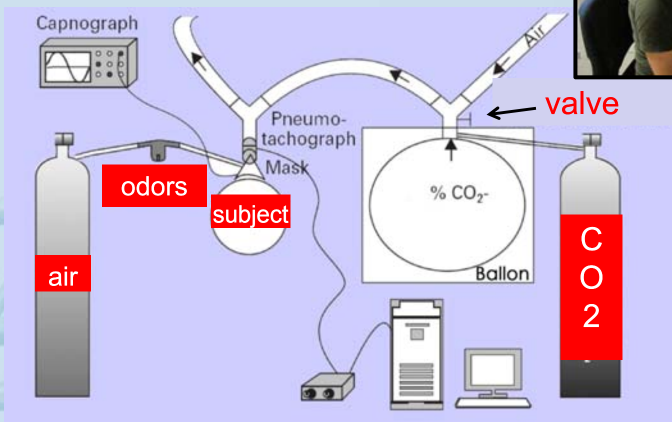
CO_2 inhalation trials

- fast breathing
- smothering sensations
- chest tightness
- feelings of choking
- pounding heart
- sweating
- hot flushes
- lump in throat
- headache
- tension, anxious feelings

Predictive cues

- odors
- mental images

Methods



Odor CSs

ACQUISITION

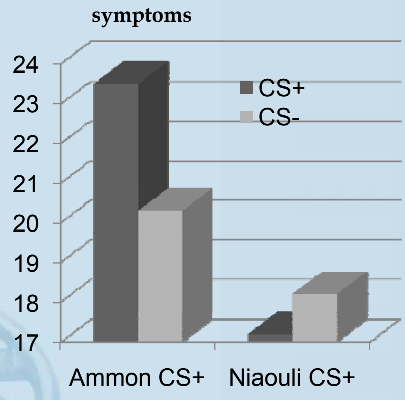
2 min breathing trials

CS+	Odor 1+	7.5 % CO_2	→	•Ventilation (f, V_T, V_E) •$FETCO_2$ •HR •Subjective symptoms
CS-	Odor 2+	room air	→	

TEST

CS+	Odor 1+	room air	→	•Ventilation (f, V_T, V_E) •$FETCO_2$ •HR •Subjective symptoms
CS-	Odor 2+	room air	→	

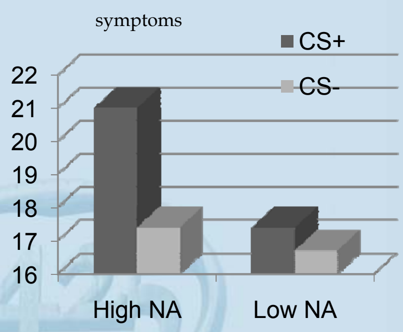
Acquired symptoms to harmless odors

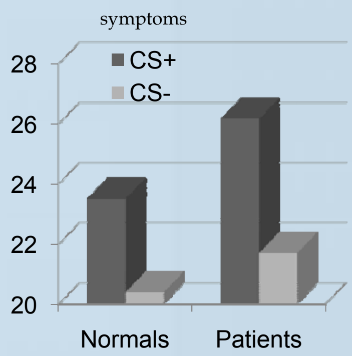


- Symptom learning to unpleasant odor only!
- No difference in contingency awareness

Van den Bergh et al., 1995, 1997, 1999

More elevated in high NA and in clinical MUS patients





Van den Bergh et al., 1998, 1999

Respiratory learning paradigm

ACQUISITION

10 s + 80 s

CS+	Odor 1+	HypC HV	→
CS-	Odor 2+	NorC HV	→

- Ventilation (f, V_T, V_E)
- $FETCO_2$
- **TCD**
- Lightheadedness

TEST

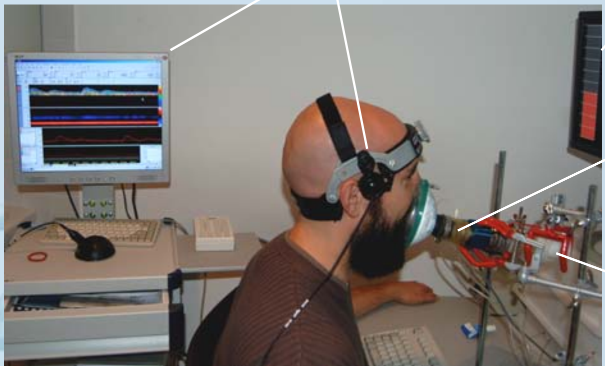
CS+	Odor 1+	NorC HV	→
CS-	Odor 2+	NorC HV	→
CS+	Odor 1+	Norm Br	→
CS-	Odor 2+	Norm Br	→

- Ventilation (f, V_T, V_E)
- $FETCO_2$
- **TCD**
- Lightheadedness

Transcranial Doppler Ultrasonography

TCD

Online LH rating scale



Respiratory measures

CO_2 added through inspiratory tube

Mid Cerebral Artery (MCA)

2.1 Transcranial Doppler measure

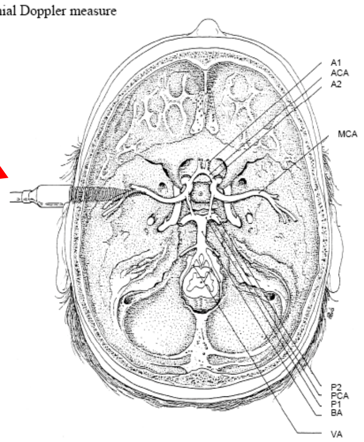
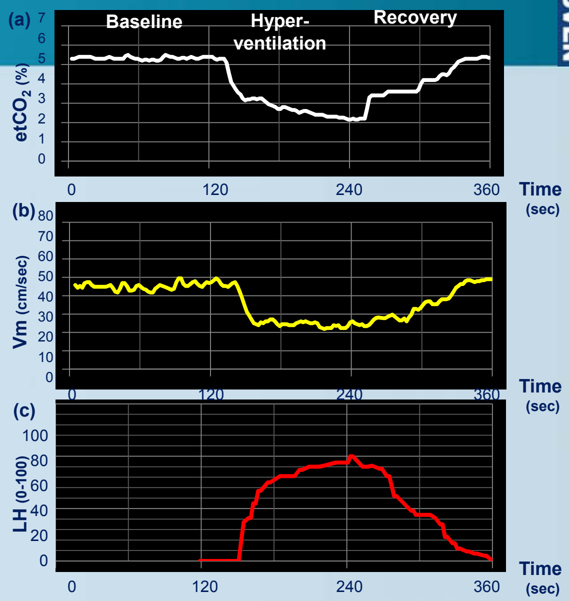


Fig 2. Insonated vessels using Transcranial Doppler: The middle (MCA), anterior (ACA, with A1 and A2) en posterior (PCA, with P1 en P2) arteries may be sampled through the (trans)temporal window. The basilar (BA) and vertebral (VA) arteries can also be measured, which is through the transforamenal (sucoccipital) window. Figure adopted from Stroobant & Vingerhoets (2000).

End-tidal CO_2
(fractional concentration)

Cerebral Blood Flow
(mean velocity in rMCA)

Lightheadedness
(rating 0-100)

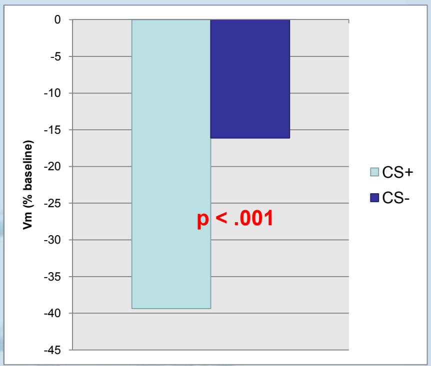


(a) $FetCO_2$ (b) Vm (c) LH during 3 phases in 1 subject

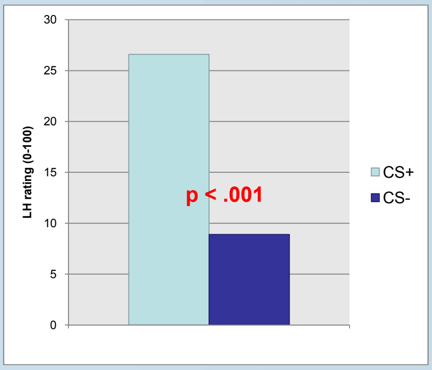
Learning phase

Mean within-s r = -0.64 ±0.17

CBF – rMCA



Max Lightheadedness

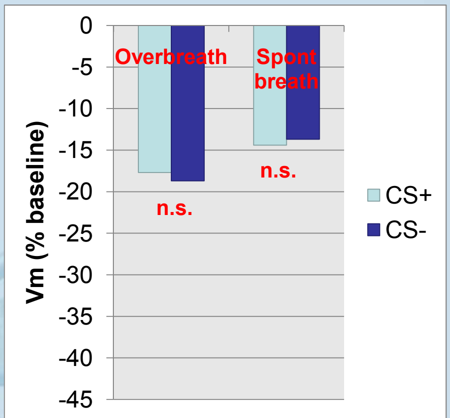


Bresseleers et al., Psych Med., in press

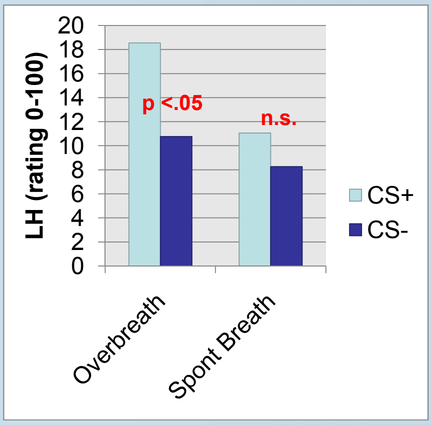
Test phase

Mean within-s r = -0.04 ±0.24

CBF – rMCA



Max LH



Bresseleers et al., Psych Med., in press

The rise and fall of the "hyperventilation syndrome"

Hyperventilation syndrome ?

- Because there was no 1-1 relationship between a self-reported (anxiety/panic) symptom and reduced $PetCO_2$
  - HVS has been dropped, but also HV as a stress response
- Taboo, to the benefit of physiotherapists?

Anxiety

- Faster breathing
- Reduced "duty cyle time"
  - (Ti/Ttot : greater proportion of inspiratory time of total breathing cycle; Van Diest et al., 2009)

- When and why hypocapnic breathing?
- Important role for interoceptive fear conditioning?
-

Other implications

- Symptom perception in asthma
  - Effects on treatment adherence and asthma control
- COPD
  - Social comparison during group rehabilitation on symptoms..
- MUS

Body – symptom correspondence

- within-subject correlation between a specific subjective report and a specific physiological response across a number of breathing trials

- Minute ventilation **- PCO_2**	**- Faster/deeper breathing** **- Breathlessness**

Role of affective context

"Test of quality of air on subjective well-being"

High and low NA normals

Negative frame	**Positive frame**
Unpleasant odor	**Pleasant odor**
"breathing this air may make you feel tensed like when being **anxious** or expecting something **terrible** to occur"	"breathing this air may make you feel tensed like when **being in love** or looking out for **something really nice** to happen"

Role of context as memory cues

Correspondence

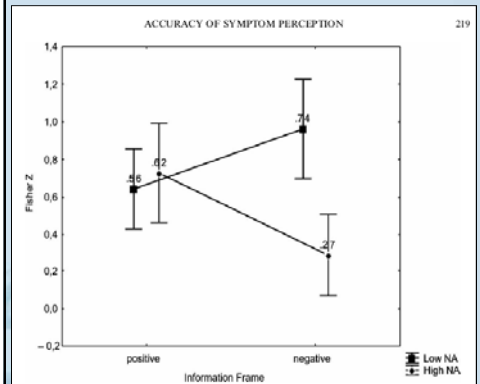
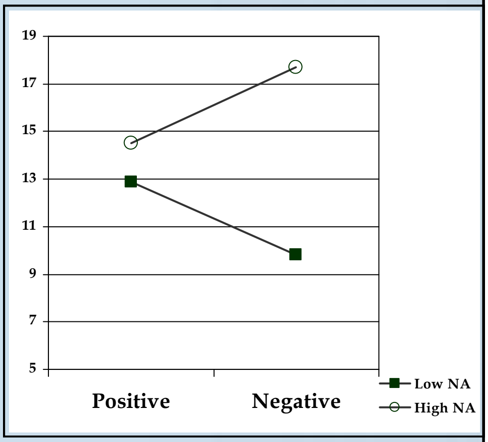


FIGURE 1 Interoceptive accuracy (Fisher-Z transformed within-subject correlations) in high and low NA persons as a function of the information frame (positive/negative). Numbers located near datapoints indicate backtransformed correlations. Vertical bars indicate confidence intervals (0.95).

Symptom Level



Van den Bergh et al., P&H, 2004

Semantic cues

- within-subject correlation between a specific subjective report and a specific physiological response across a number of breathing trials

neutral

- **Minute ventilation**	- **Faster/deeper breathing**
- **PCO_2**	- **Breathlessness**

Semantic cues

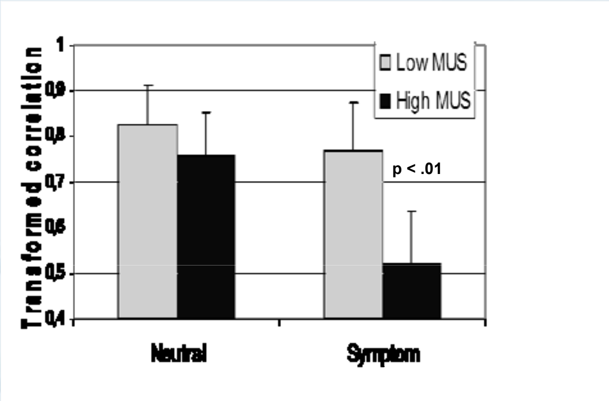
- within-subject correlation between a specific subjective report and a specific physiological response across a number of breathing trials

- Minute ventilation	**- Faster/deeper breathing**
- PCO_2	**- Breathlessness**

symptom

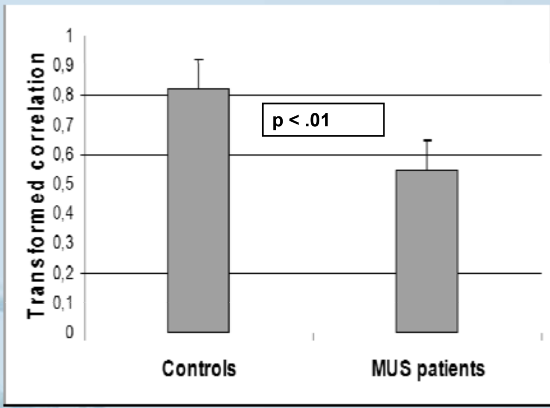
Semantic cues : Neutral vs Symptom rating

High and low symptom reporters (normals)



Bogaerts et al., JPR, 2008

Clinical MUS patients -

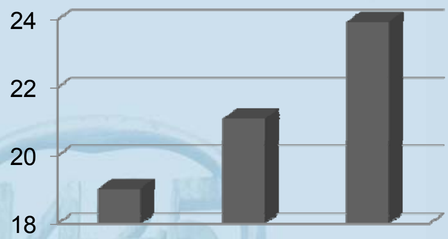


Bogaerts et al., 2010

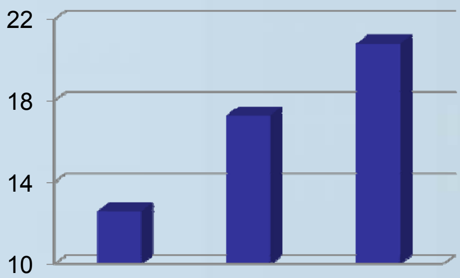
Chronic Fatigue Patients

Brief induction of negative affective state
Imagery scripts (2 min)

Negative affect (state)



Typical CFS Symptoms



Bogaerts et al., BRaT, 2007

Conclusions

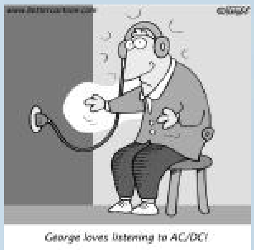
- Relationship between peripheral physiology and interoceptive processes in the brain is quite “plastic”
- Basic learning mechanisms can shape interoceptive processes
- High trait NA more vulnerable to “somatovisceral illusions”
  - More fusing of affect with somatic information?
  - Relevance for somatization disorders, “functional syndromes”
- Role of deficient inhibitory control from rightPFC in high NA/MUS?

EMOTION ↔ BREATHING

Imagery scripts
(presented through headphones)

FEAR (elevator)

You are alone in an elevator. It is very small and has no ventilation. You start feeling short of breath. It slowly becomes unbearable. You want to leave this place as soon as possible, but when the elevator stops the door is stuck. You are sweating and your heart pounds wildly. In despair, you start pushing all the buttons, but nothing helps. You perspire heavily and gasp for breath. It appears that there is almost no air available anymore in this little place. Your heart leaps into your mouth, while you pull on the door with all your strength. It remains jammed shut. Everything becomes black.



Emotional Imagery and $FetCO_2$

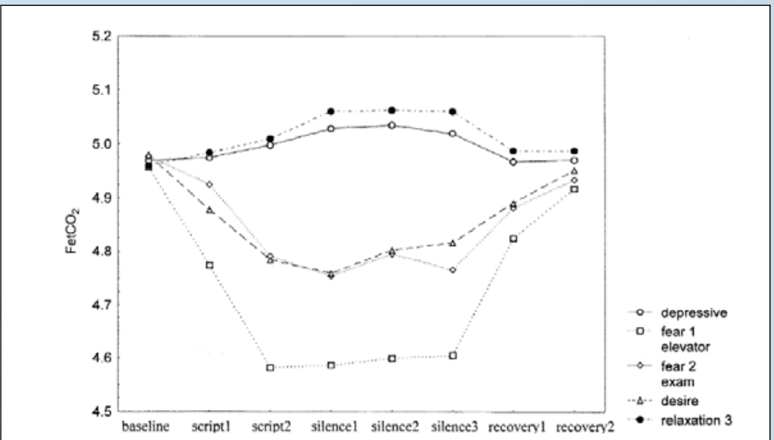


Figure 1. Mean $FetCO_2$ (per 30-s periods) for each imagery trial (last 30 s of baseline, 60 s script, 90 s silence, 60 s recovery).

Van Diest, et al., 2001

Imagining suffocation

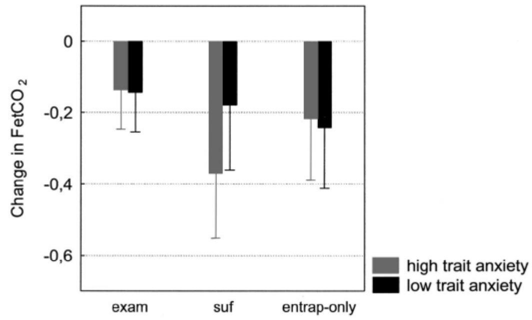
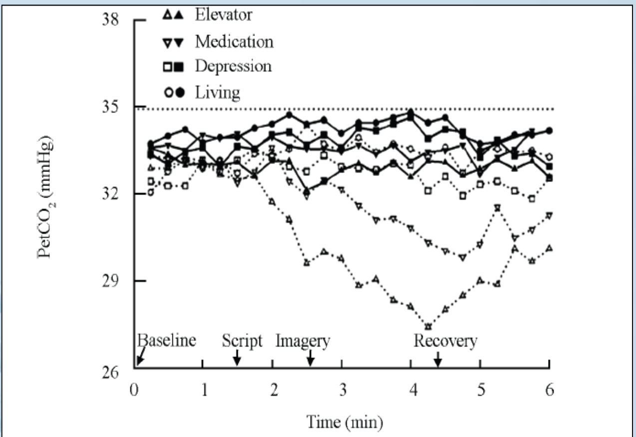


Figure 1. Mean change in $FetCO_2$ in high- and low-trait anxious participants during imagery of the examination, the suffocation (suf), and the entrapment-only (entrap-only) scripts. Vertical bars denote 0.95 confidence intervals.

Psychosomatic Medicine 67:813–819 (2005)

Imagining suffocation



Healthy

MUD

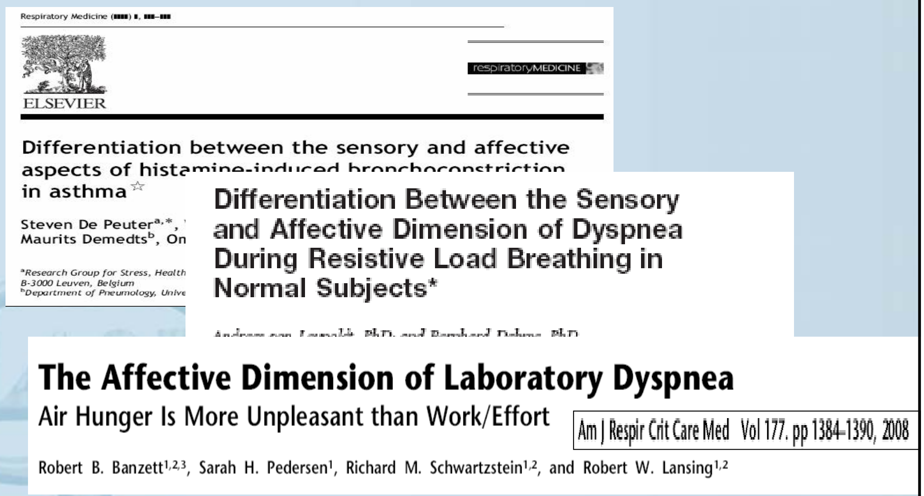
Han et al., (2008). *Chin Med J*

Imagining suffocation

- Mental imagery of stressful scenes
  (e.g. being blocked in elevator) triggers
  - Dyspnea
  - Hyperventilation (↓ $PetCO_2$)
- In anxious healthy persons (Van Diest et al., 2001; 2005)
- In patients with medically unexplained dyspnea (Han et al., 2008)
  - ↓ $PetCO_2$ does not explain all dyspnea
  - Mismatch between emotion-related **drive** and **actual ventilation** (?)

DEFENSIVE RESPONSE MOBILIZATION TO DYSPNEIC SENSATIONS

Differentiation sensory - affective aspect


Respiratory Medicine

ELSEVIER

respiratoryMEDICINE

Differentiation between the sensory and affective aspects of histamine-induced bronchoconstriction in asthma

Steven De Peuter, Maurits Demedts, On

Research Group for Stress, Health
B-3000 Leuven, Belgium
Department of Pneumology, Unive

Differentiation Between the Sensory and Affective Dimension of Dyspnea During Resistive Load Breathing in Normal Subjects*

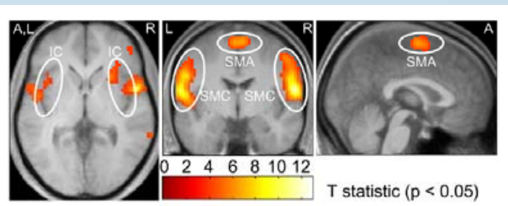
The Affective Dimension of Laboratory Dyspnea

Air Hunger Is More Unpleasant than Work/Effort

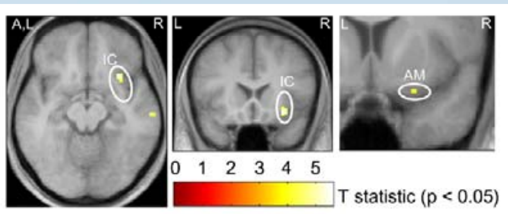
Am J Respir Crit Care Med Vol 177. pp 1384–1390, 2008

Robert B. Banzett[1,2,3], Sarah H. Pedersen[1], Richard M. Schwartzstein[1,2], and Robert W. Lansing[1,2]

Loaded breathing - effort



- Sensory aspect
  - Sensorimotor cortices
  - Supplemental motor area
  - Insula



- Unpleasantness
  - Amygdala
  - Insula

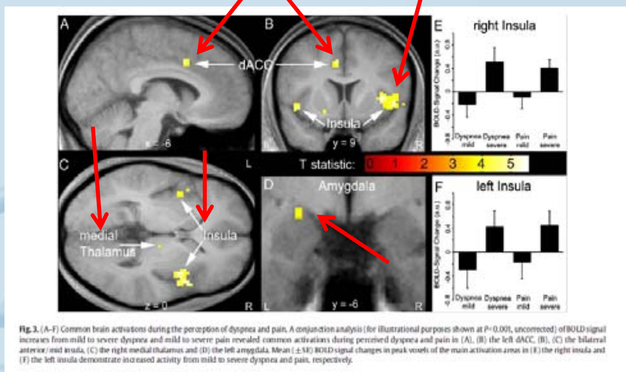
von Leupoldt et al., 2008

Dyspnea and pain

Homeostatic emotions

- pain
- dyspnea, 'air hunger'

} shared network



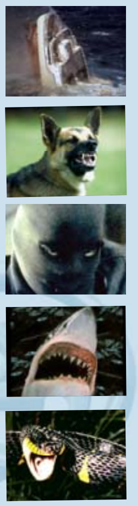
- anterior/mid insula
- dACC
- amygdala
- medial thalamus

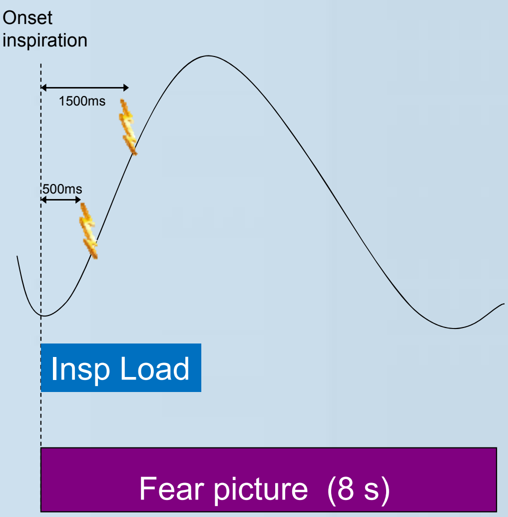
von Leupoldt et al., 2009

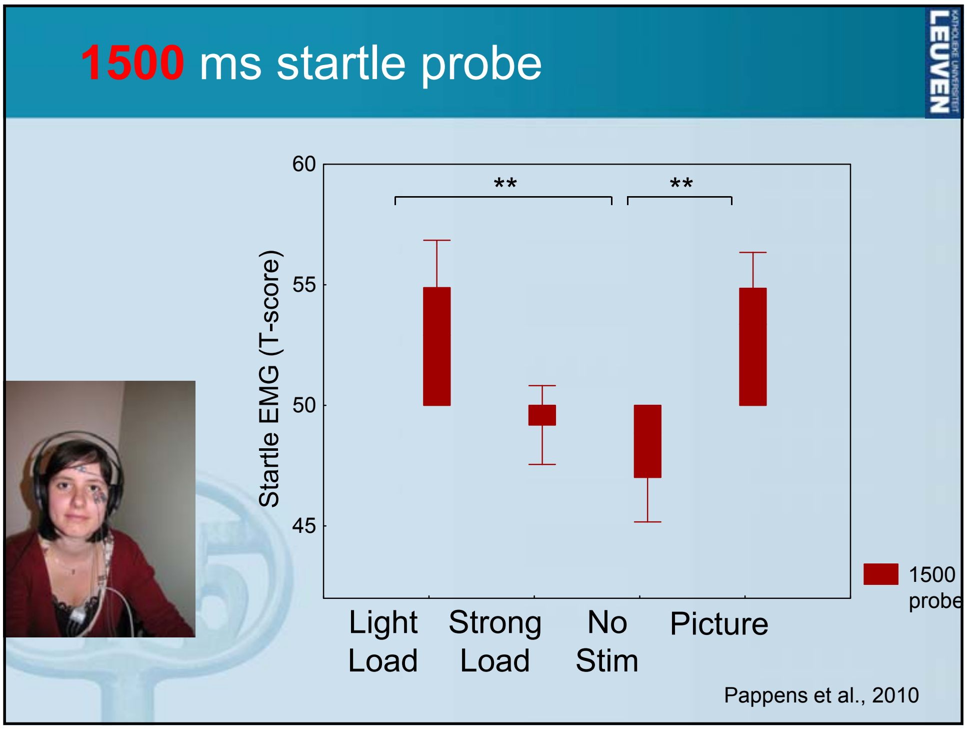
IAPS pictures - Loads

8 sec

Start at inspiratory onset






1500 ms startle probe
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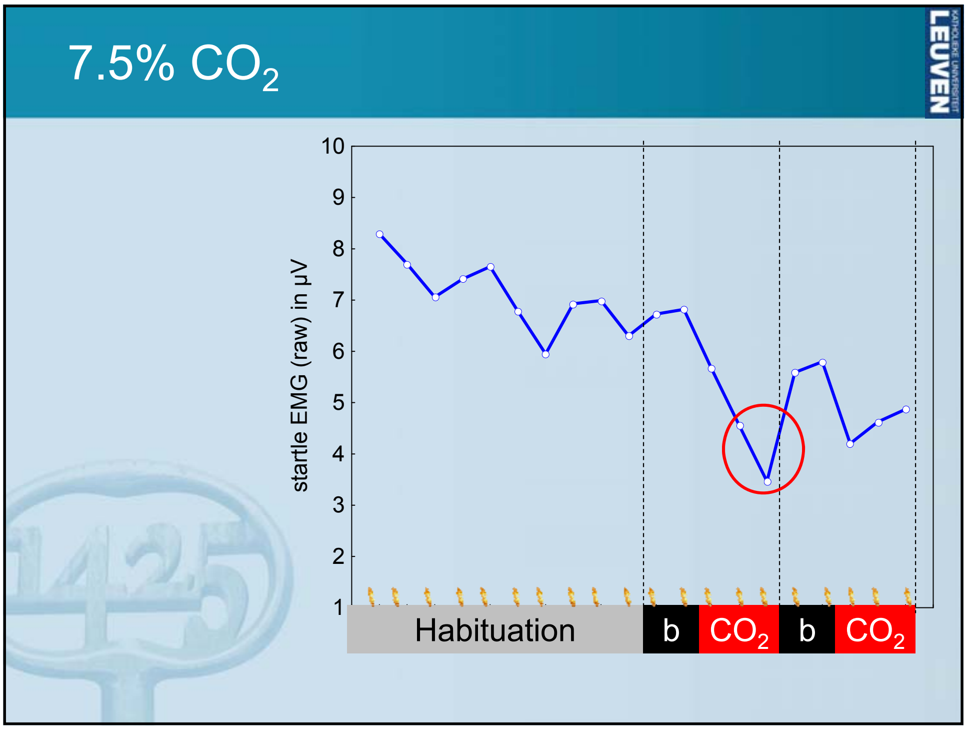
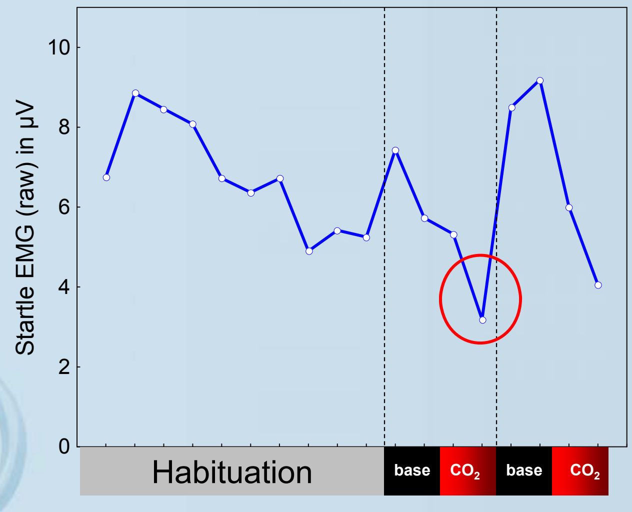
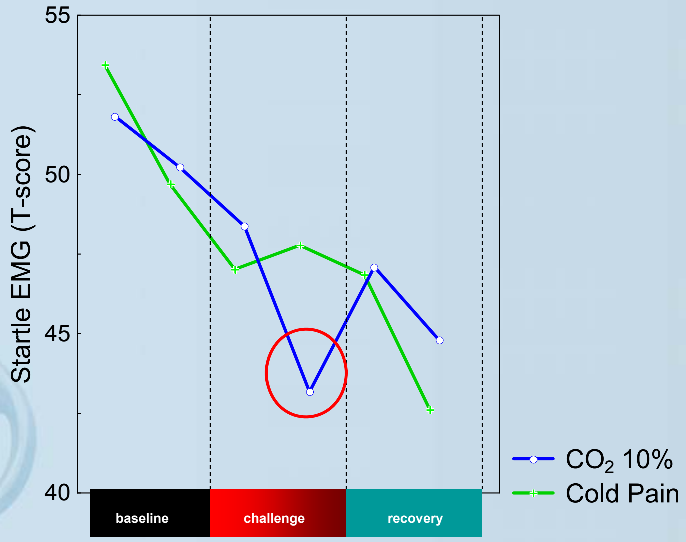
KATHOLIEKE UNIVERSITEIT
Startle EMG (T-score)
60
55
50
45
**
**
1500 probe
Light Load
Strong Load
No Stim
Picture
Pappens et al., 2010


7.5% CO_2
LEUVEN
KATHOLIEKE UNIVERSITEIT
startle EMG (raw) in µV
10
9
8
7
6
5
4
3
2
1
Habituation
b
CO_2
b
CO_2

20% CO_2



10% CO_2 - cold pressor pain (2°)



Dyspnea and startle potentiation

- No SP *during* dyspneic stimulation
  - Despite aversiveness (ratings, SCR)
  - Consistent for chemical and mechanical stimuli
  - Not related to inter-individual differences in subjective fear
  - Fear of suffocation, anxiety sensitivity, trait anxiety, state anxiety

  - SP found during (more aversive) cold pressor pain (What about visceral pain?)

- "Standard" SP found for *anticipation* of dyspneic stimuli
  - Voluntary hyperventilation — Melzig et al., 2008
  - Load-load interoceptive conditioning — Pappens et al., in prep

WHY DO YOU SIGH ?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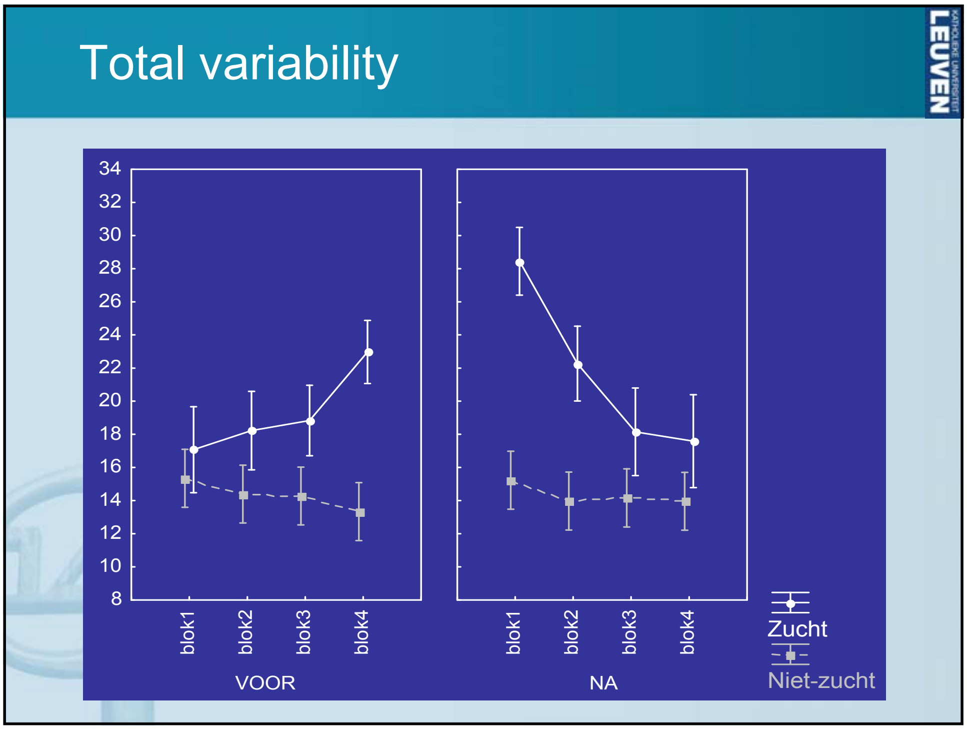
KATHOLIEKE UNIVERSITEIT
Psychophysiology, 46 (2009), 1005–1013. Wiley Periodicals, Inc. Printed in the USA.
Copyright © 2009 Society for Psychophysiological Research
DOI: 10.1111/j.1469-8986.2009.00842.x
Why do you sigh? Sigh rate during induced stress and relief
ELKE VLEMINCX,
KATLEEN BOGAE
Research Group on Healt
Physiology & Behavior 101 (2010) 67–73
Contents lists available at ScienceDirect
Physiology & Behavior
journal homepage: www.elsevier.com/locate/phb
ELSEVIER
Take a deep breath: The relief effect of spontaneous and instructed sighs
Elke Vlemincx a,*, Joachim Taelman b, Ilse Van Diest a, Omer Van den Bergh a
Biological Psychology 84 (2010) 82–87
Contents lists available at ScienceDirect
Biological Psychology
journal homepage: www.elsevier.com/locate/biopsycho
ELSEVIER
Respiratory variability preceding and following sighs: A resetter hypothesis
Elke Vlemincx a, Ilse Van Diest a, Paul M. Lehrer b, André E. Aubert c, Omer Van den Bergh a,*
a Research Group on Health Psychology, Department of Psychology, University of Leuven, Tiensestraat 102, B-3000 Leuven, Belgium
b Department of Psychiatry, Robert Wood Johnson Medical School, University of Medicine and Dentistry of New Jersey, Piscataway, NJ, United States
c Division of Experimental Cardiology, Department of Cardiovascular Diseases, University of Leuven, Belgium


Total variability
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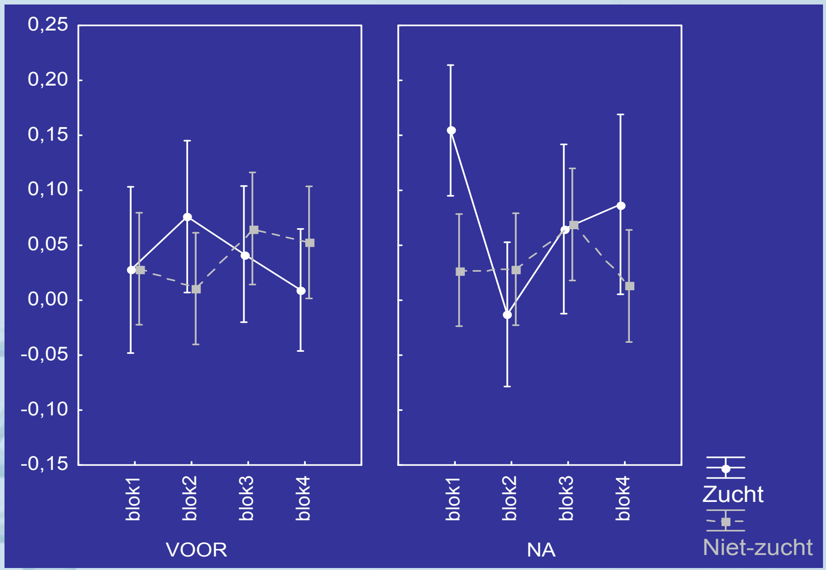
34
32
30
28
26
24
22
20
18
16
14
12
10
8
blok1
blok2
blok3
blok4
VOOR
blok1
blok2
blok3
blok4
NA
Zucht
Niet-zucht

Structured variability



BREATHING AND RELAXATION

Manipulation breathing

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- Rate
  - 6 breaths/min ??
  - Psychological effects?

Effect of rosary prayer and yoga mantras on autonomic cardiovascular rhythms: comparative study

Luciano Bernardi, Peter Sleight, Gabriele Bandinelli, Simone Cencetti, Lamberto Fattorini, Johanna Wdowczyc-Szulc, Alfonso Lagi

BMJ VOLUME 323 22–29 DECEMBER 2001

Conclusion Rhythm formulas that involve breathing at six breaths per minute induce favourable psychological and possibly physiological effects.

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Slow Breathing Increases Arterial Baroreflex Sensitivity in Patients With Chronic Heart Failure

Luciano Bernardi, MD; Cesare Porta, MD; Lucia Spicuzza, MD; Jerzy Bellwon, MD; Giammario Spadacini, MD; Axel W. Frey, MD; Leata Y.C. Yeung, MD; John E. Sanderson, MD; Roberto Pedretti, MD; Roberto Tramarin, MD

Conclusions—These data suggest that in patients with CHF, slow breathing, in addition to improving oxygen saturation and exercise tolerance as has been previously shown, may be beneficial by increasing baroreflex sensitivity. (*Circulation*. 2002;105:143-145.)

Slow Breathing Improves Arterial Baroreflex Sensitivity and Decreases Blood Pressure in Essential Hypertension

Chacko N. Joseph, Cesare Porta, Gaia Casucci, Nadia Casiraghi, Mara Maffeis, Marco Rossi, Luciano Bernardi

Hypertension October 2005 DOI: 10.1161/01.HYP.0000179581.68566.7d

Memory for dyspnea..

HOW WAS YOUR DYSPNEA LATELY?

Rebreathing test (Read, 1967)

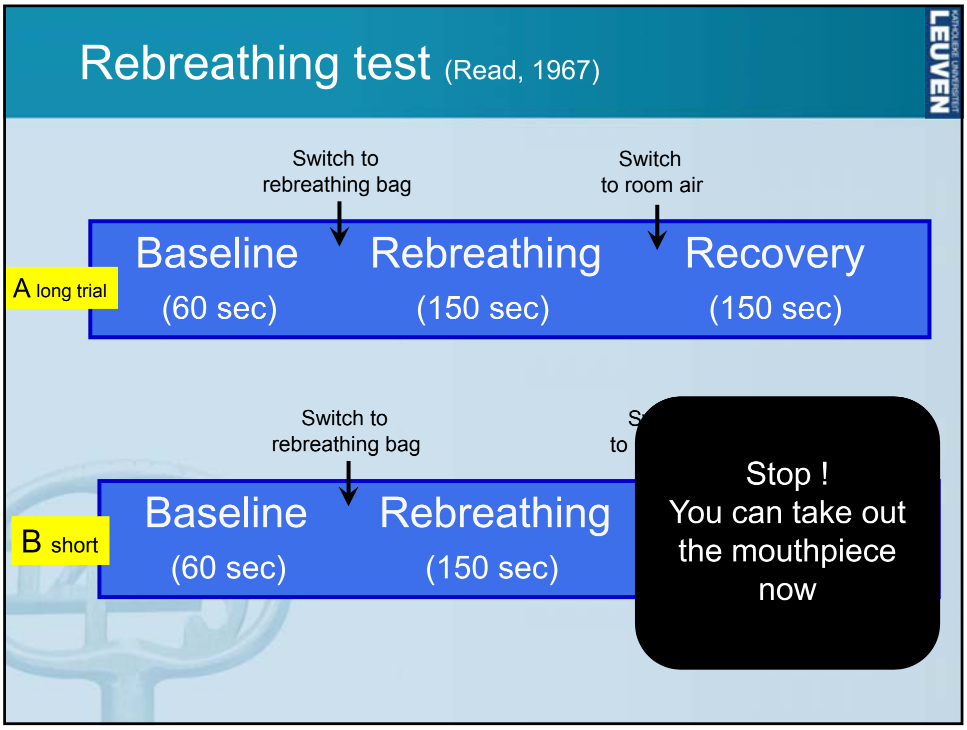
Switch to rebreathing bag

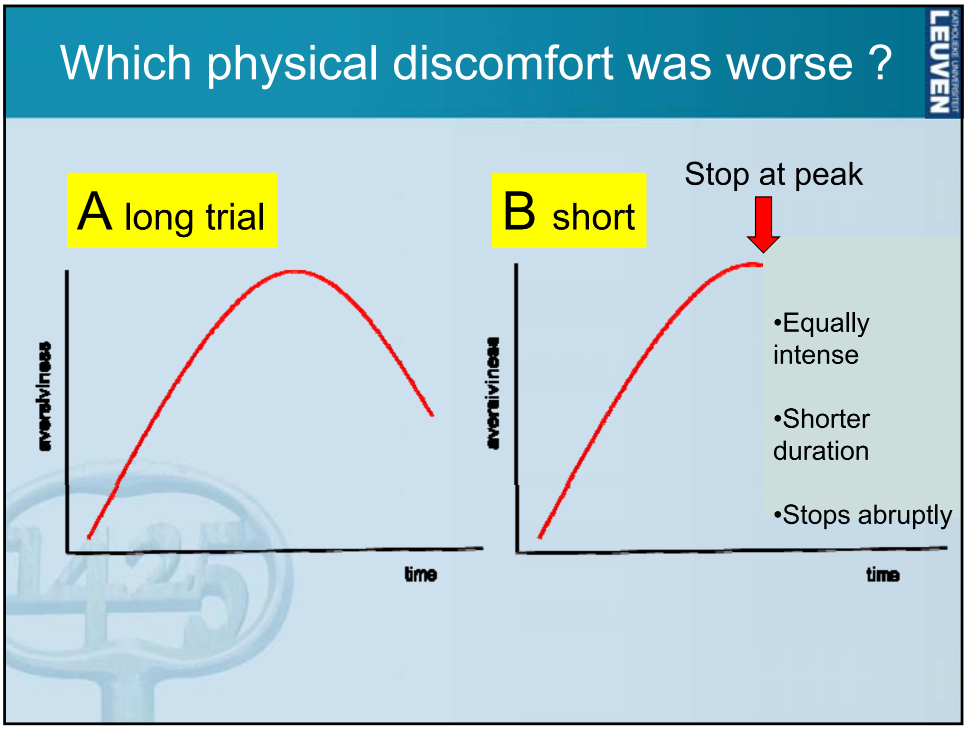
Switch to room air

Baseline	Rebreathing	Recovery
(60 sec)	(150 sec)	(150 sec)

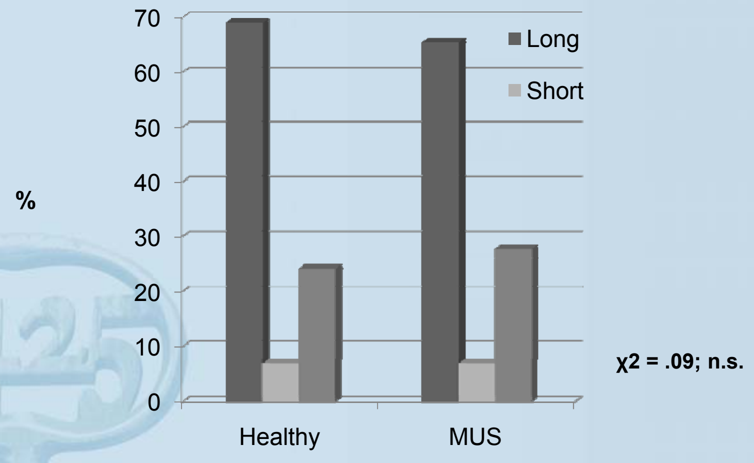
Online dyspnea rating (every 10 sec)

- ↑ PCO_2
- ↑ ventilation
- ↑ breathlessness

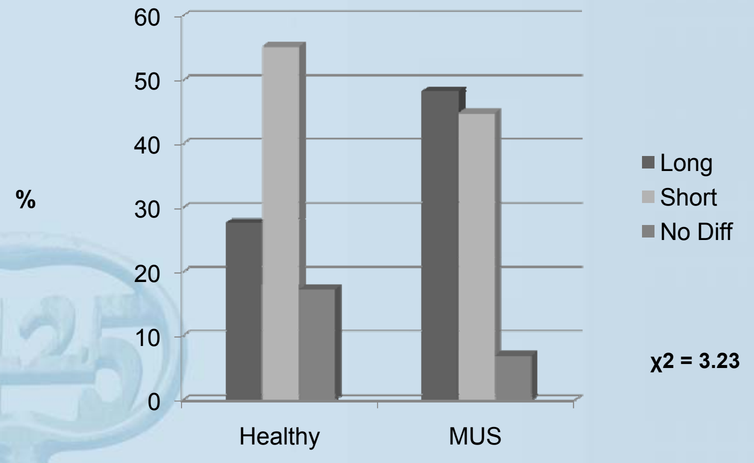

Rebreathing test (Read, 1967)
LEUVEN
Switch to rebreathing bag
Switch to room air
A long trial
Baseline (60 sec)
Rebreathing (150 sec)
Recovery (150 sec)
Switch to rebreathing bag
B short
Baseline (60 sec)
Rebreathing (150 sec)
Stop ! You can take out the mouthpiece now


Which physical discomfort was worse ?
LEUVEN
A long trial
B short
Stop at peak
•Equally intense
•Shorter duration
•Stops abruptly
time
time

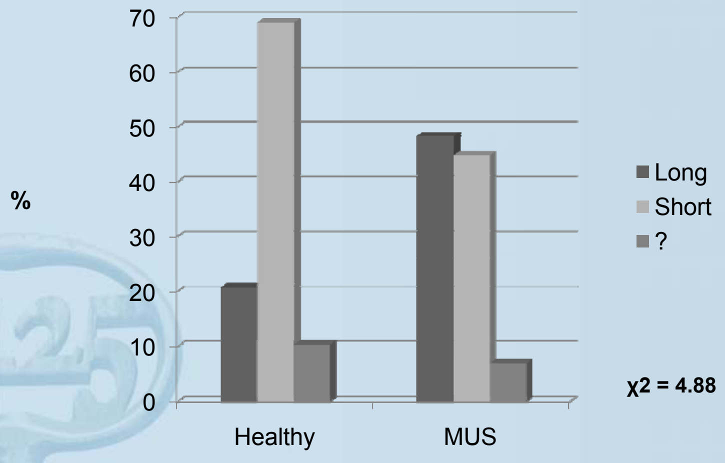
Which trial lasted longer?



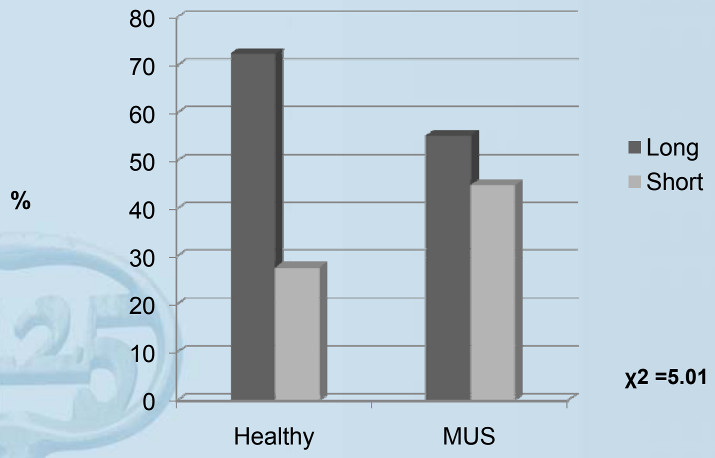
Which trial caused the greatest dyspnea at peak?



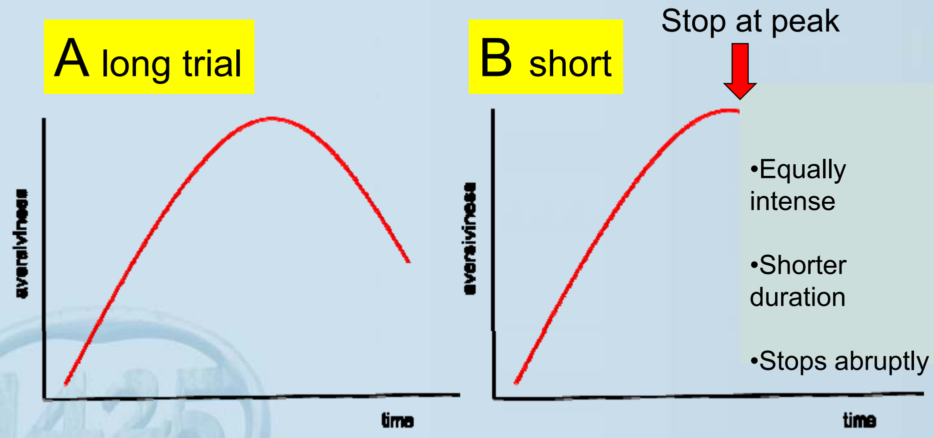
Which trial caused greatest discomfort?



Which trial would you prefer to repeat tomorrow?



Which physical discomfort was worse ?



- Equally intense
- Shorter duration
- Stops abruptly

peak-end rule : A preferred to B

→ adding more aversive stimulation makes memory of it more positive

Peak-end rule

- Experience (emotional, somatic) is encoded
  - **not** as an integration of all elements with equal weight,
  - but in the form of transitions and singular critical moments
- Memory of the chain of sensations is determined by
  - Segment that felt most intense (peak)
  - Sensations in the final segment (end)
  - Relative duration neglect

Kahneman (2000)

Thank you

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www.ppw.kuleuven.be/ogp