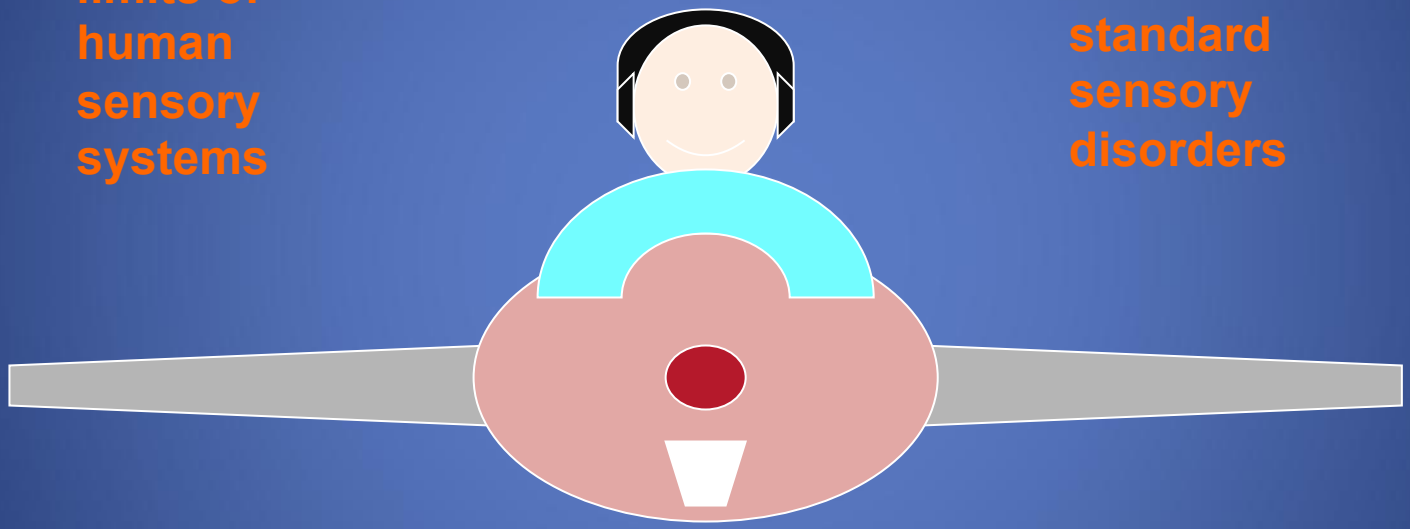
An introduction to motion sickness

Col. CSArn Marco Lucertini, MD

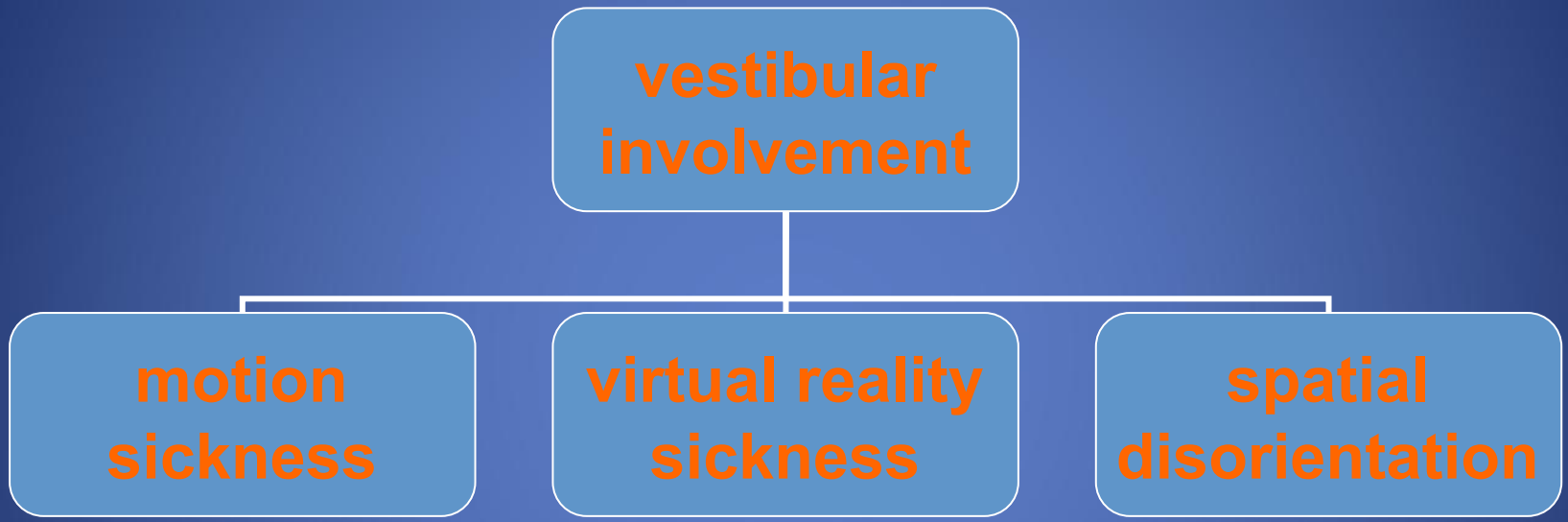
Italian Air Force

limits of human sensory systems

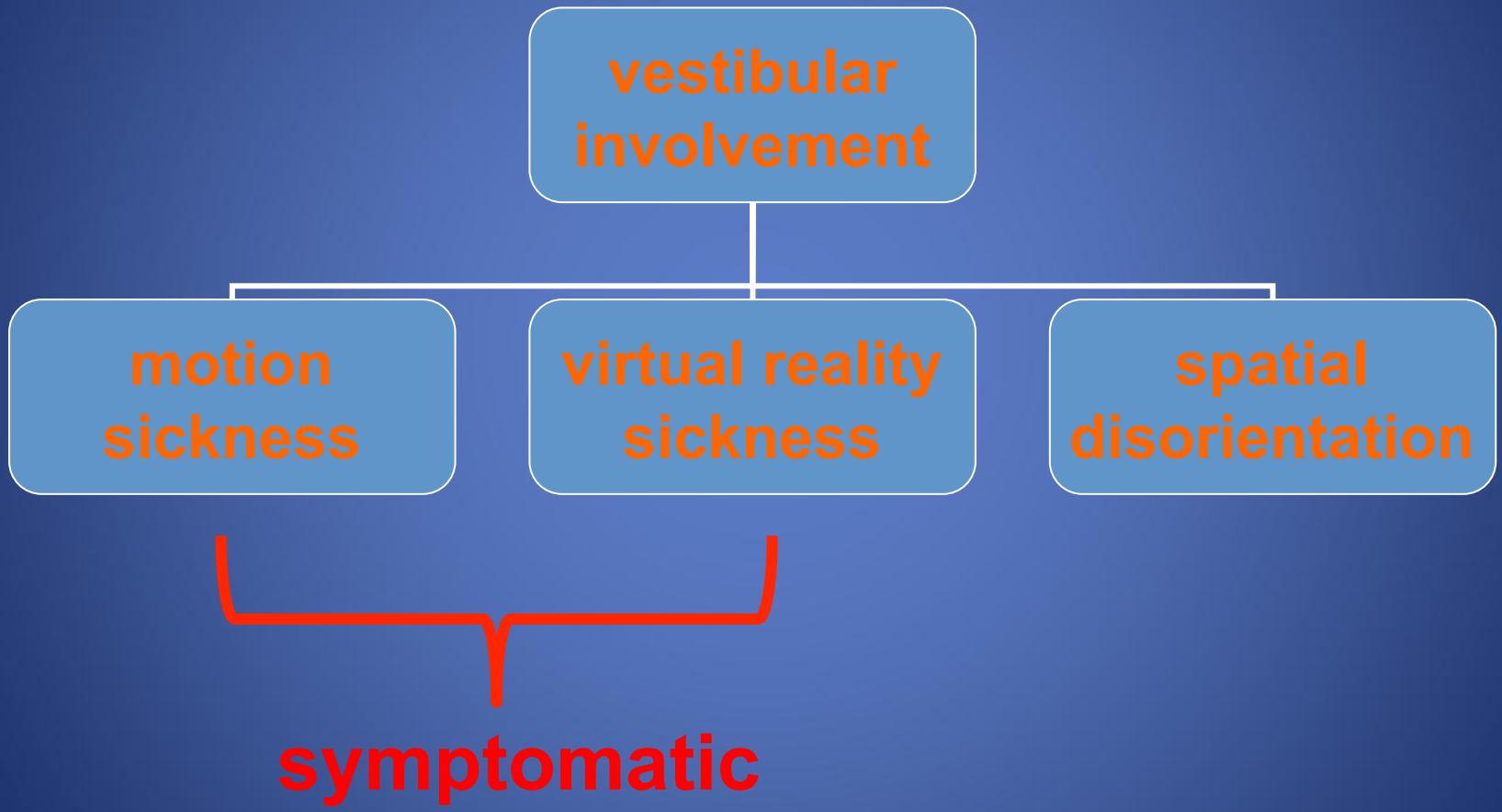


standard sensory disorders

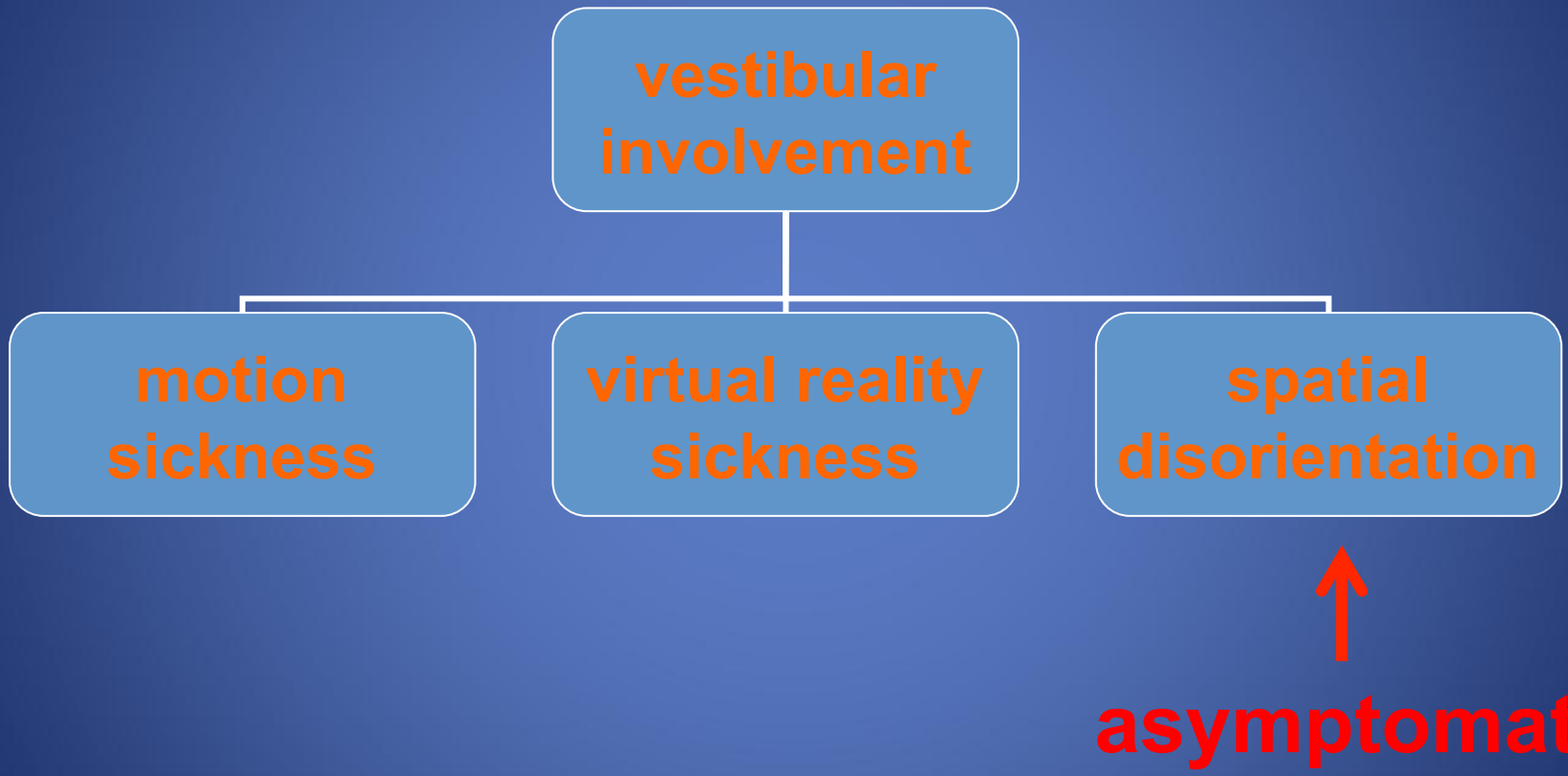
Flight Environment



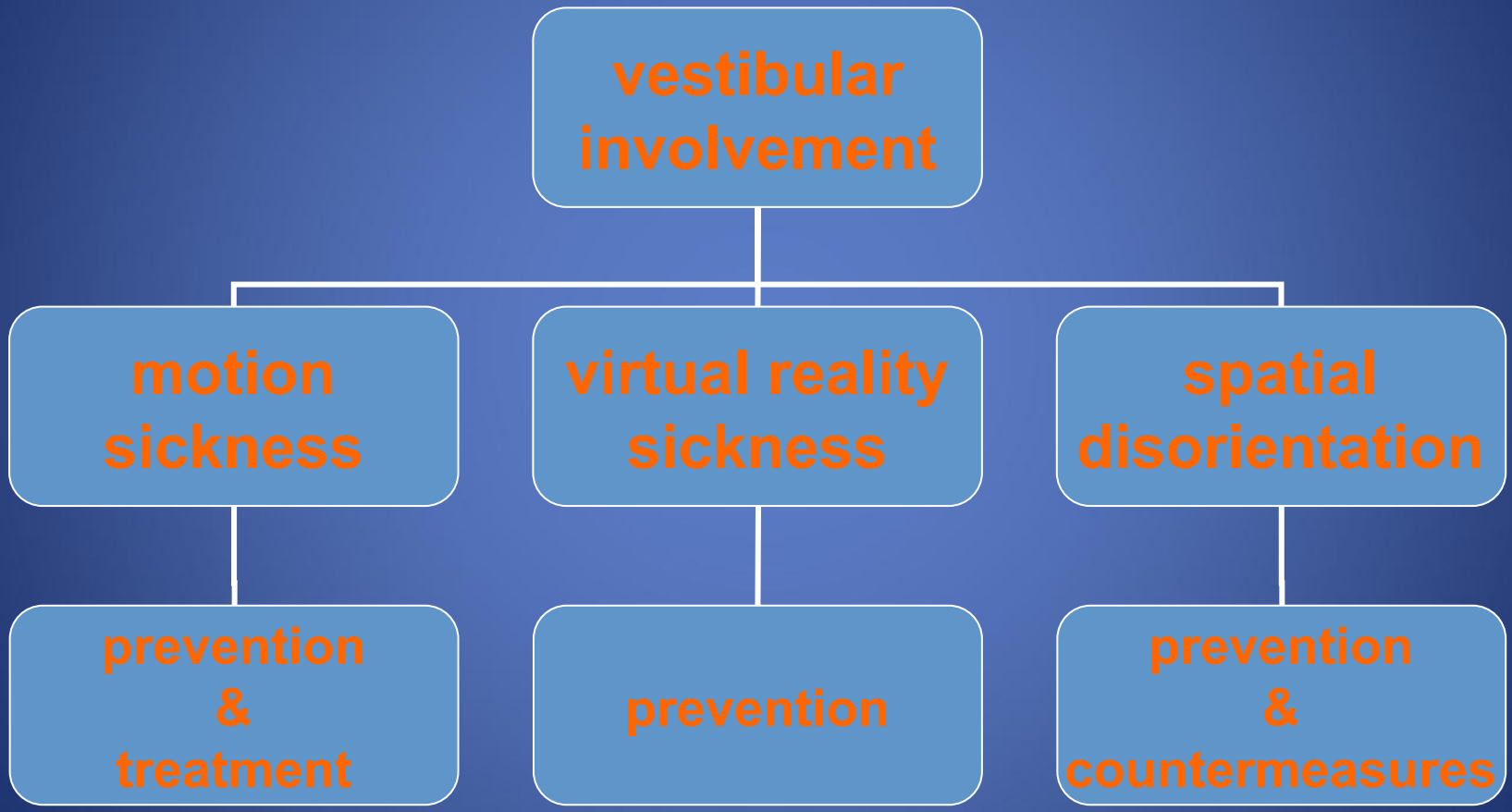
Athmospheric Environment



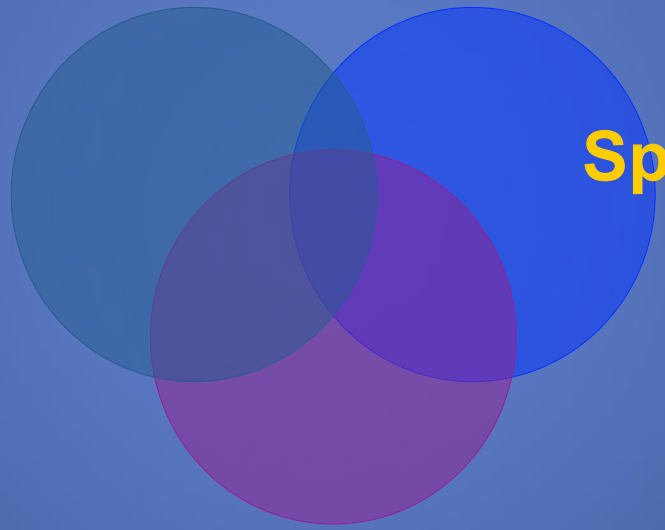
Athmospheric Environment



Athmospheric Environment



human motion related syndromes in aerospace environments



Simulator Sickness

Space Adaptation Syndrome

Motion Sickness

Motion Sickness (MS)

MS is a complex syndrome due to a real or simulated passive exposure to a moving environment.

It is characterized by various early signs and/or symptoms (headache, pallor, drowsiness, paraesthesia, sweating and others), sometimes not reported, and under prolonged exposures systematically induces nausea and vomiting.

Motion Sickness

- Sea – Sickness
- Car/Land - Sickness
- Air - Sickness
- Space - Sickness
- Virtual Reality - Sickness
  Simulator - Sickness
- ……. - Sickness

Motion Sickness in spacecrew

- Sea – Sickness
- Car/Land - Sickness
- Air - Sickness
- Space - Sickness
- Virtual Reality - Sickness
  Simulator - Sickness
- ..... - Sickness

… nec ipse iactationem navis pati posset, taedium vitae et fugae cepit.

Tito Livio: “ab urbe condita libri”

libro CXX (frammento)

Sea-sickness in the ItAF

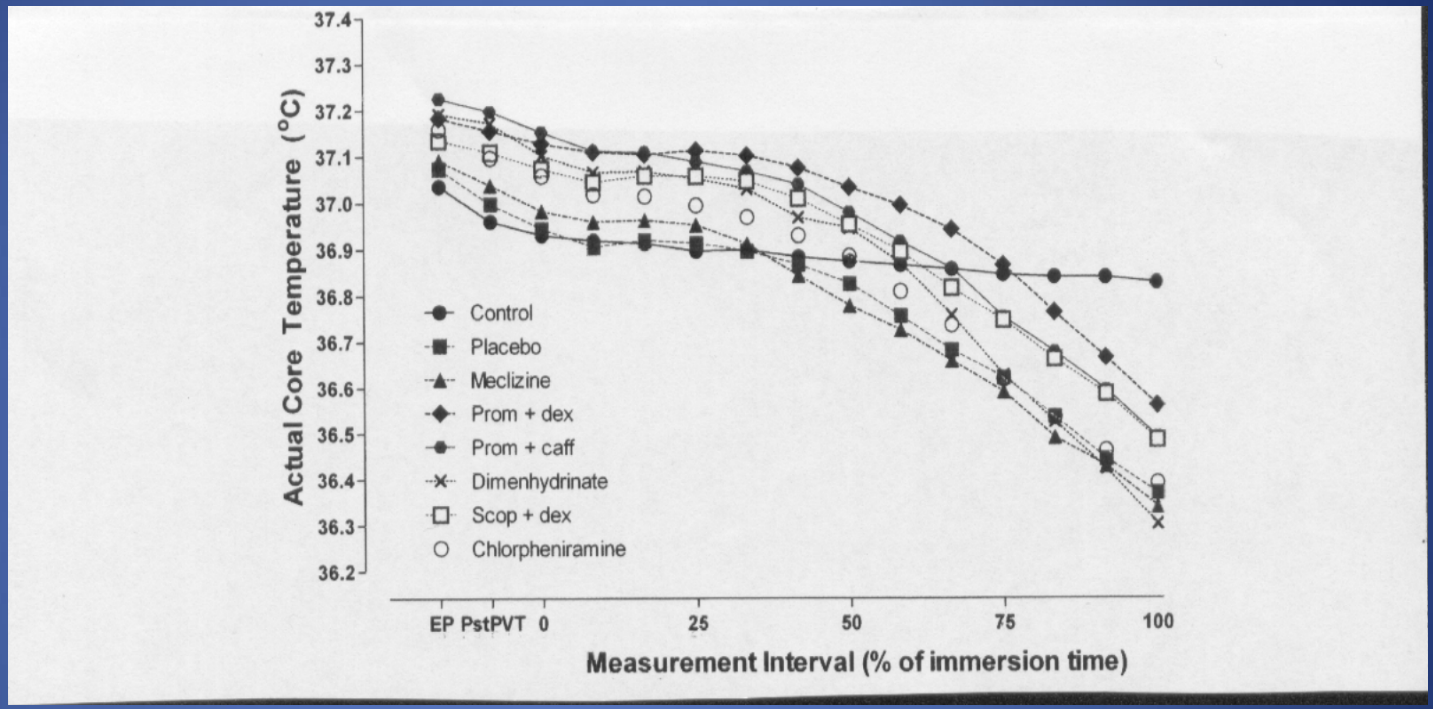
15% incidence during controlled exercises

MS facilitates the onset of hypothermia in cold environments

MS pharmacological prevention reduces/delays the onset of hypothermia (Cheung et al. 2011)

ναυς

nausea

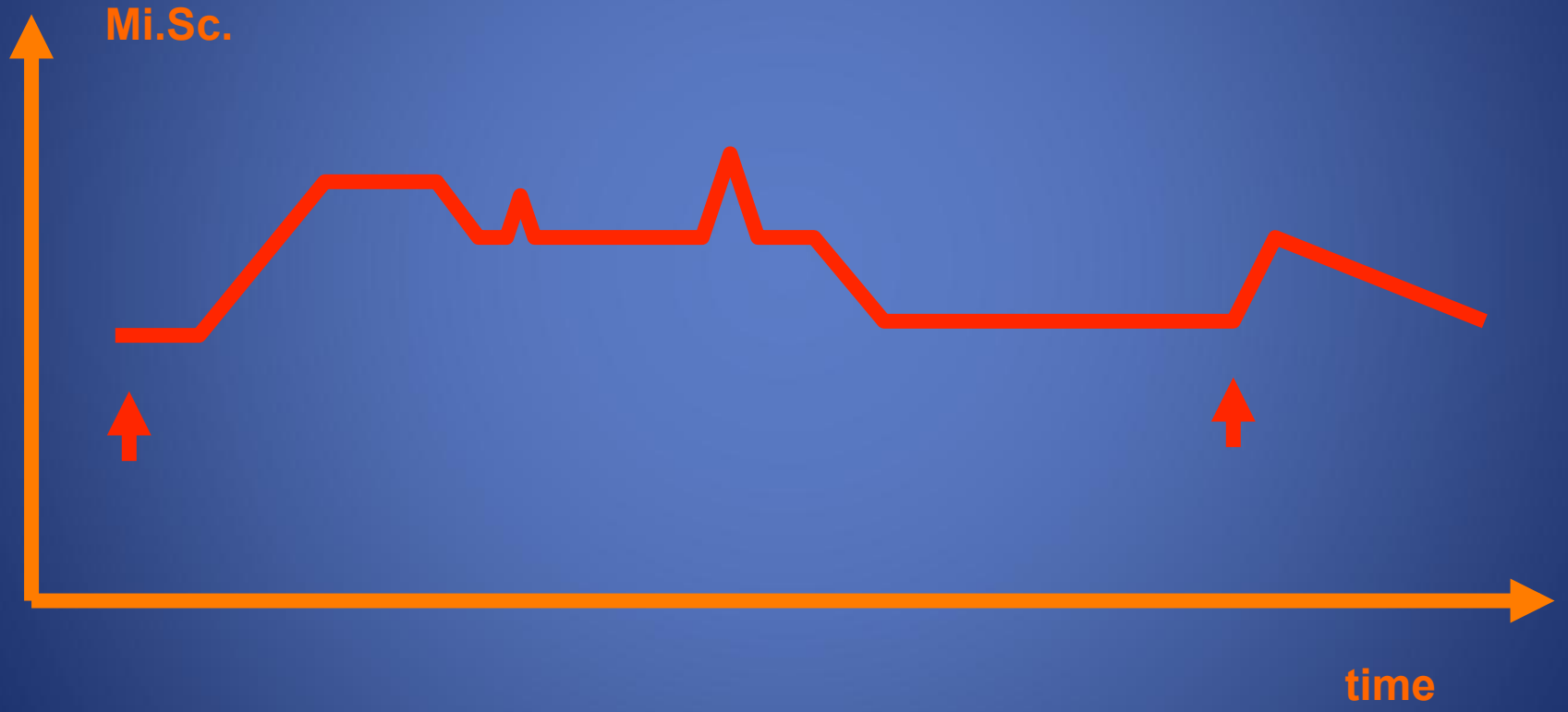


(from Cheung et al., ASEM 82: 409-15, 2011)

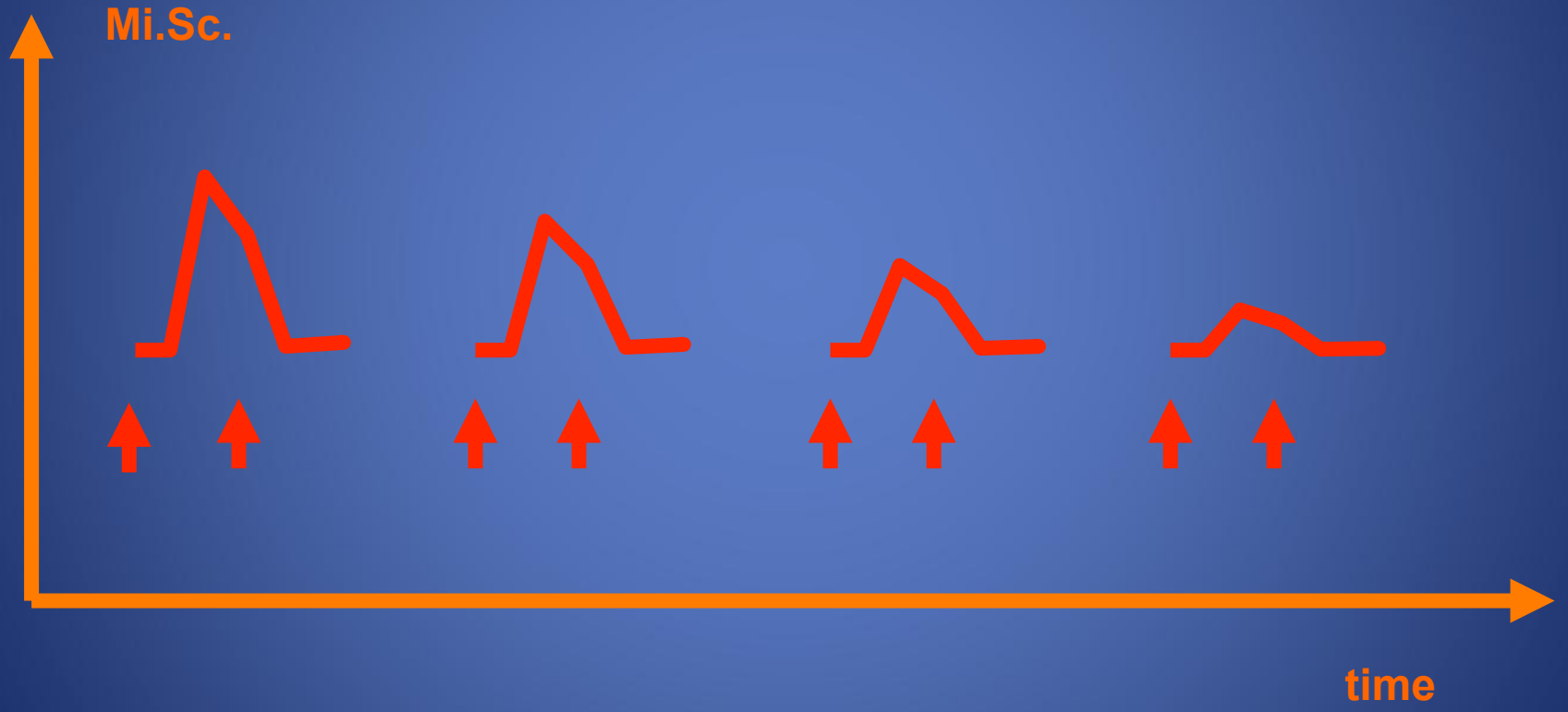
MS and environmental stimulation

Environment	Incidence	Source
Sea-sickness	62%	Turner & Griffin 1995
Space-sickness	75%	Oman et al. 1990
Air-sickness	35%	Lucertini et al. 2008

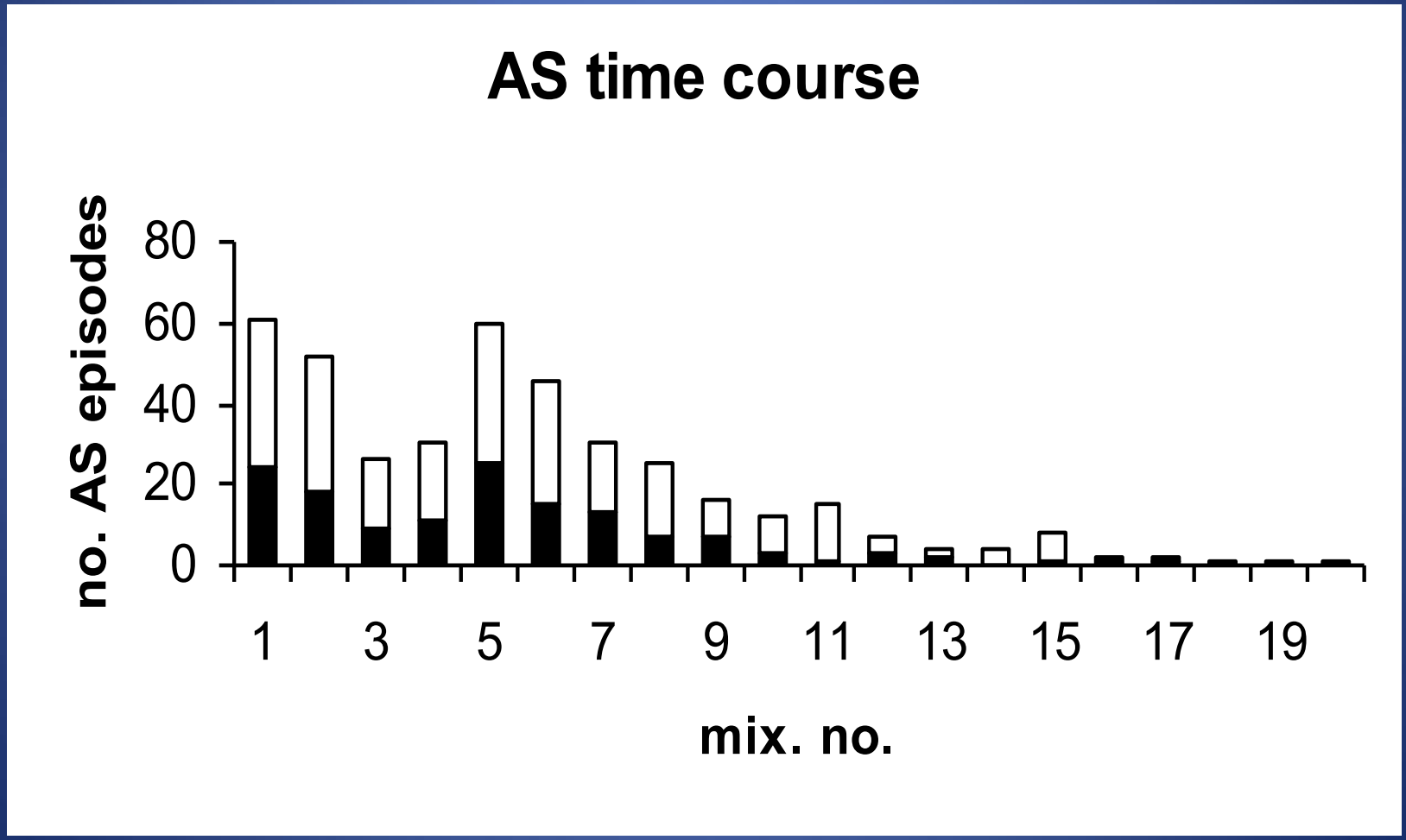
Time course of MS symptoms
(for prolonged and continuous stimuli)



Time course of MS symptoms
(for short-lasting and repeated stimuli)

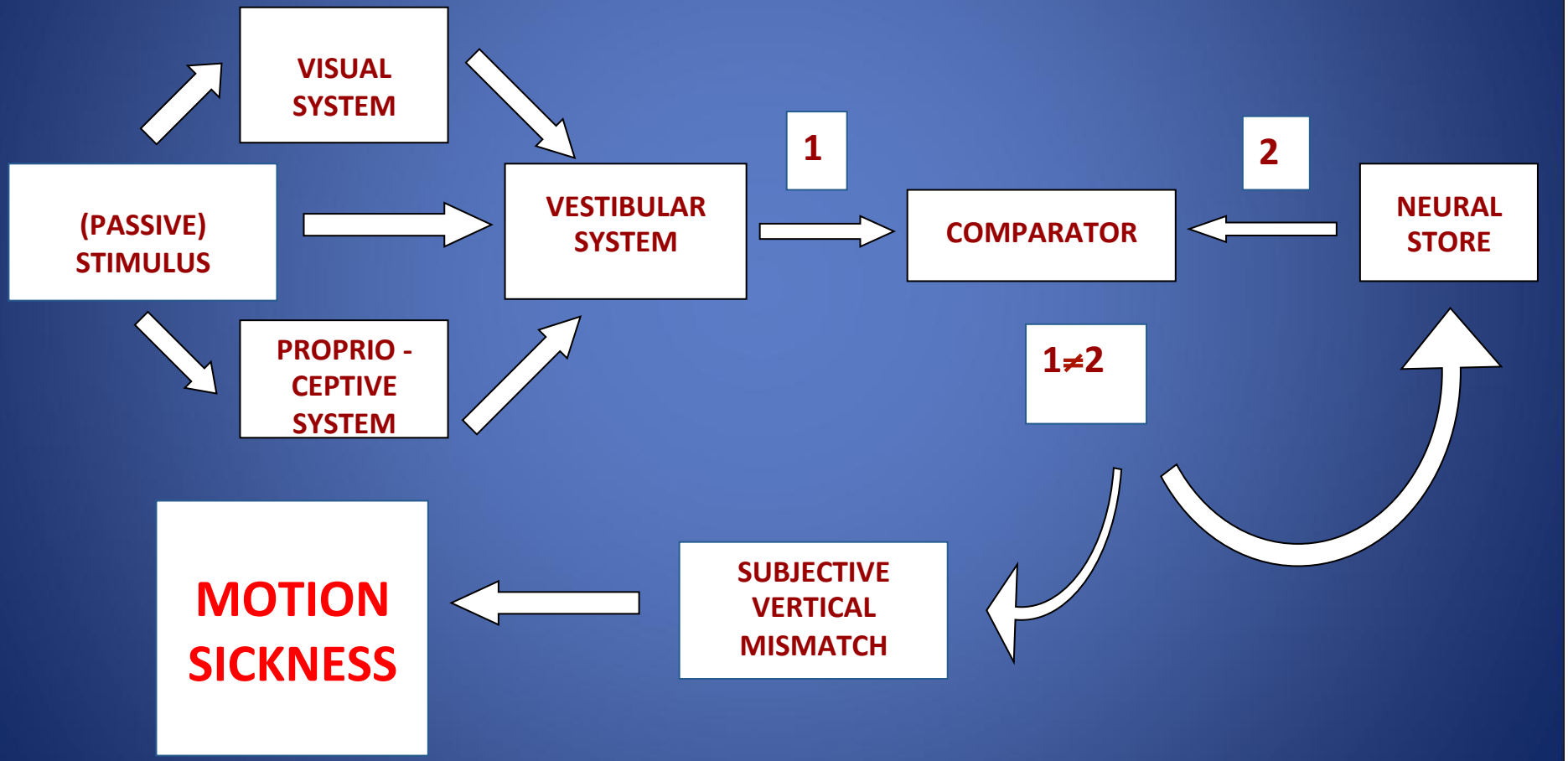


AS follow up in student pilots



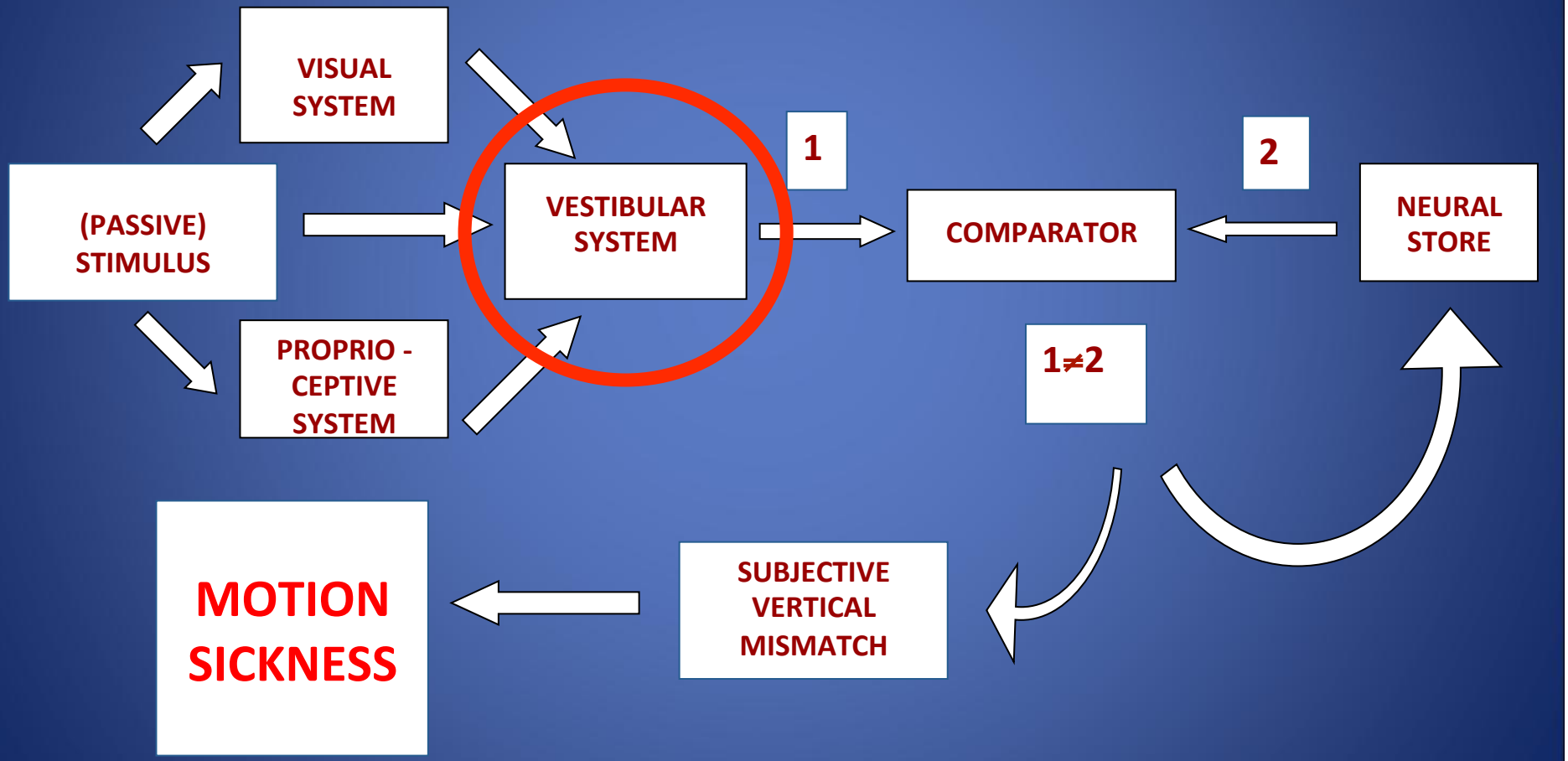

Etiopathogenesis
negative reinforcement
genetics
sensory conflict
subjective vertical mismatch
sloshing of the blood
intestinal contraction
macular asymmetries
rock-a-bye baby
poison theory

Sensory conflict theory



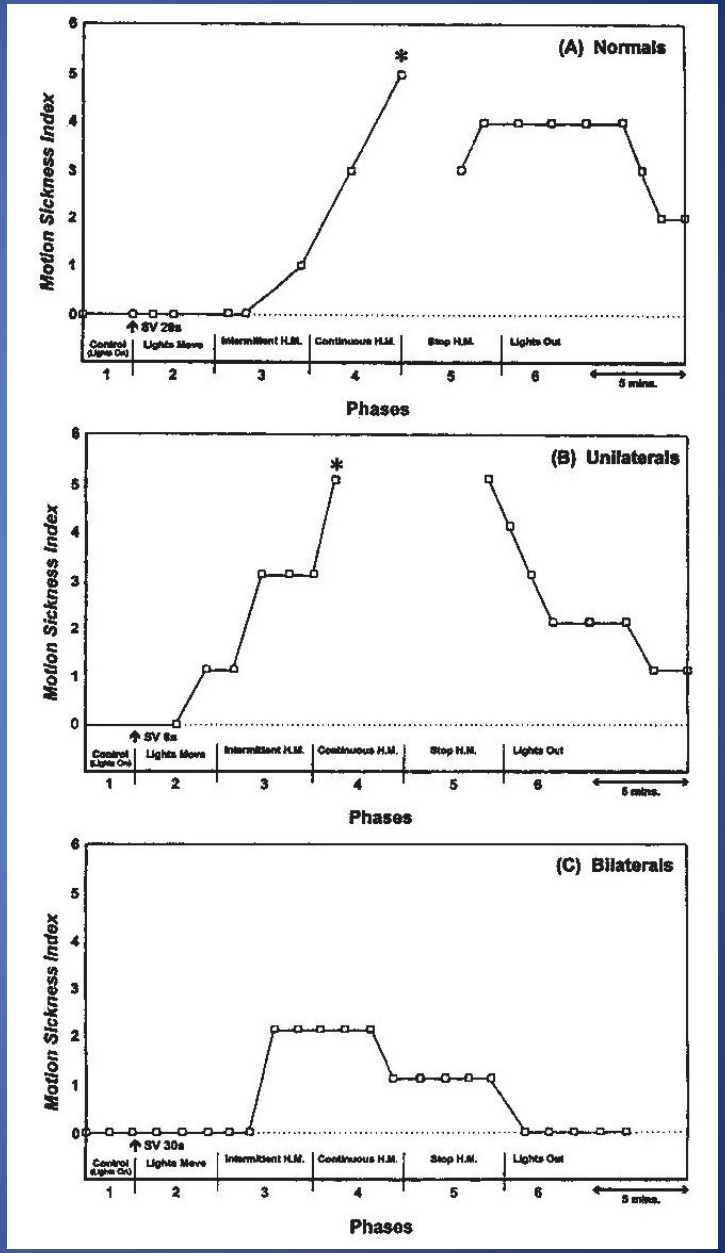
(modified from Lucertini & Lugli, 2004)

Sensory conflict theory

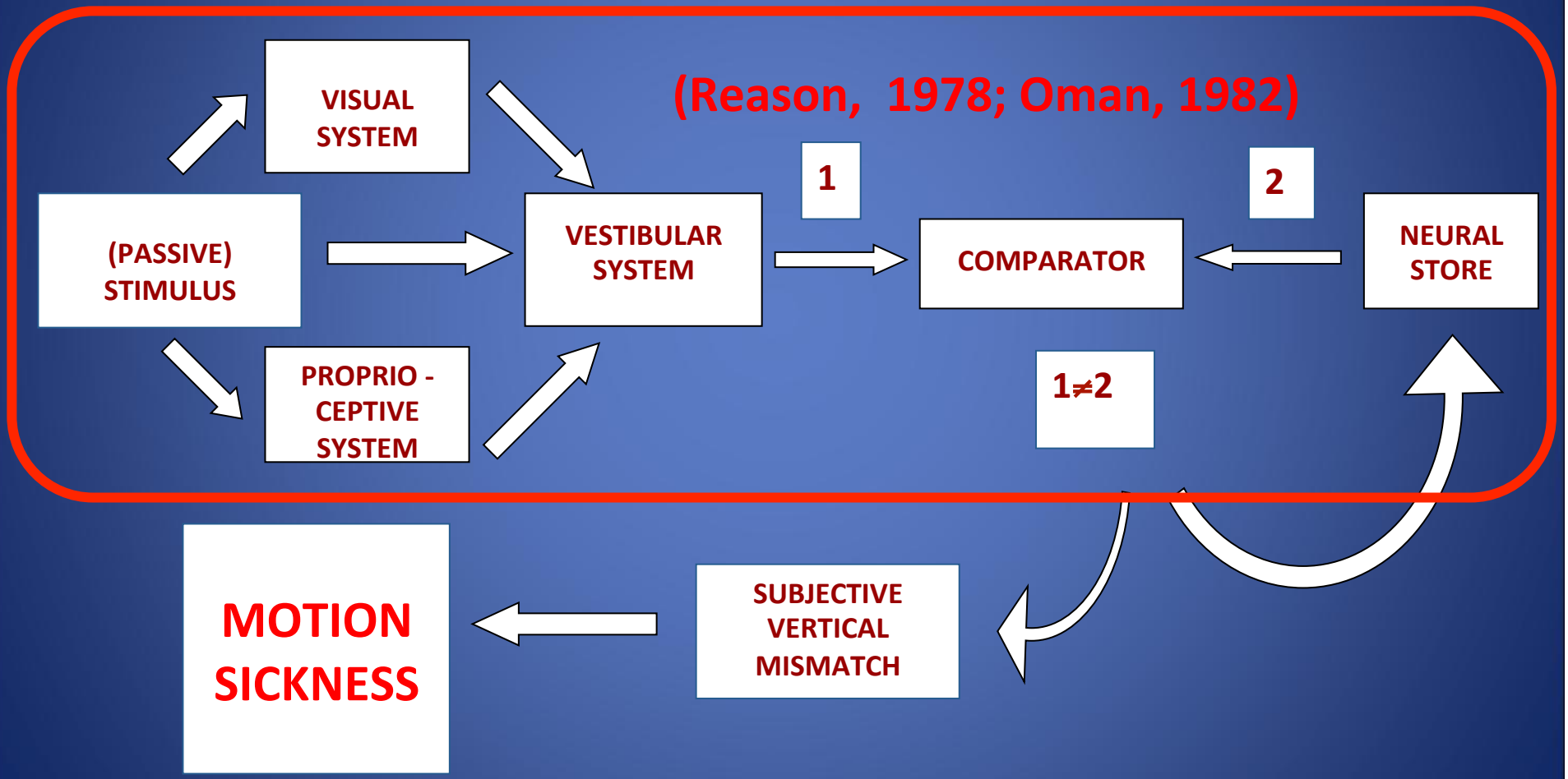


(modified from Lucertini & Lugli, 2004)

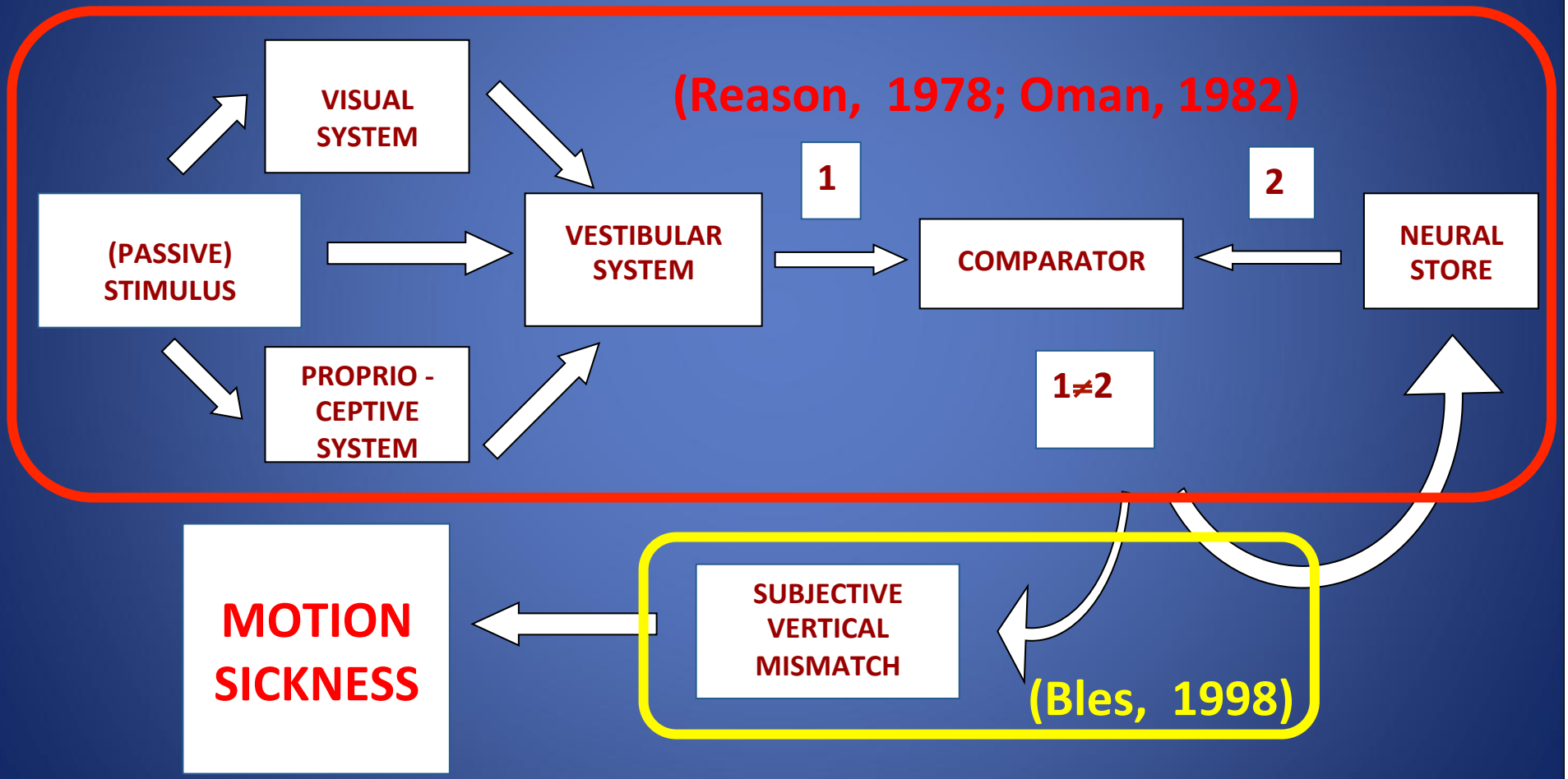
from Johnson et al.
(J. Vest. Res. 1998)



Sensory conflict theory

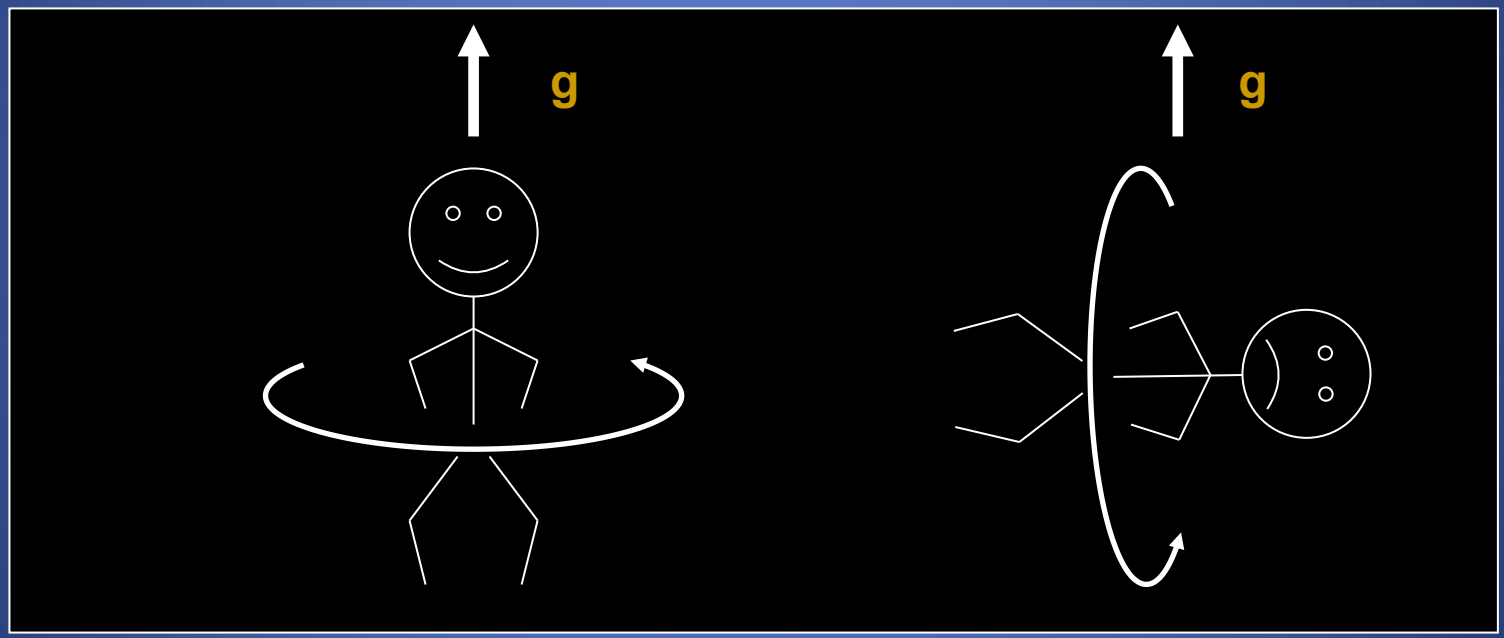


Sensory conflict theory



motion sickness

only when changes in gravity vector occur



from W. Bles (with permission)

Bomarzo's tilted house

Skylab M131 experiment

during spaceflight, the same individuals resulted no more sensitive to an identical nauseogenic stimulus (Coriolis' phenomenon) after adaptation to microgravity

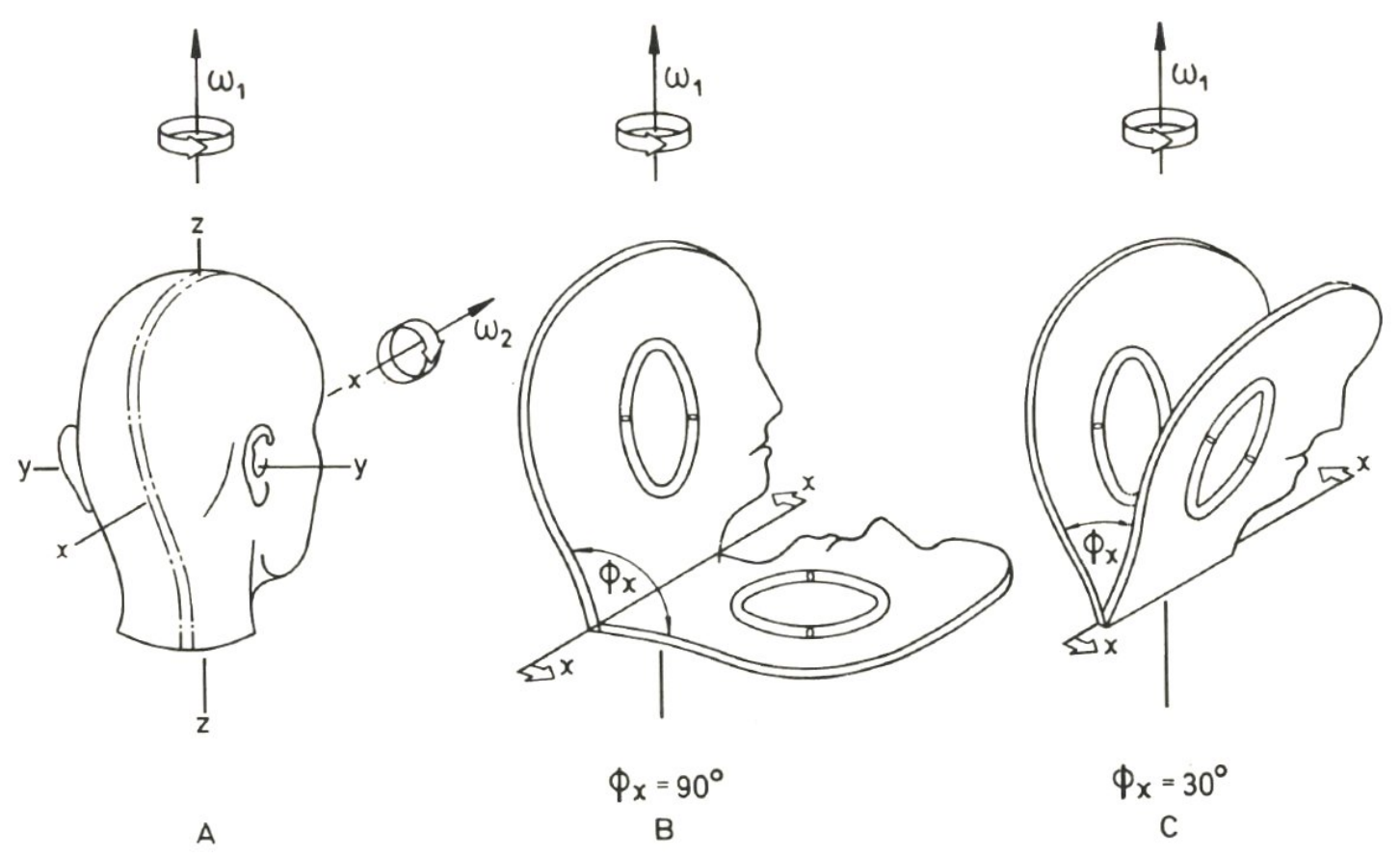
Coriolis' acceleration

Coriolis' acceleration & force

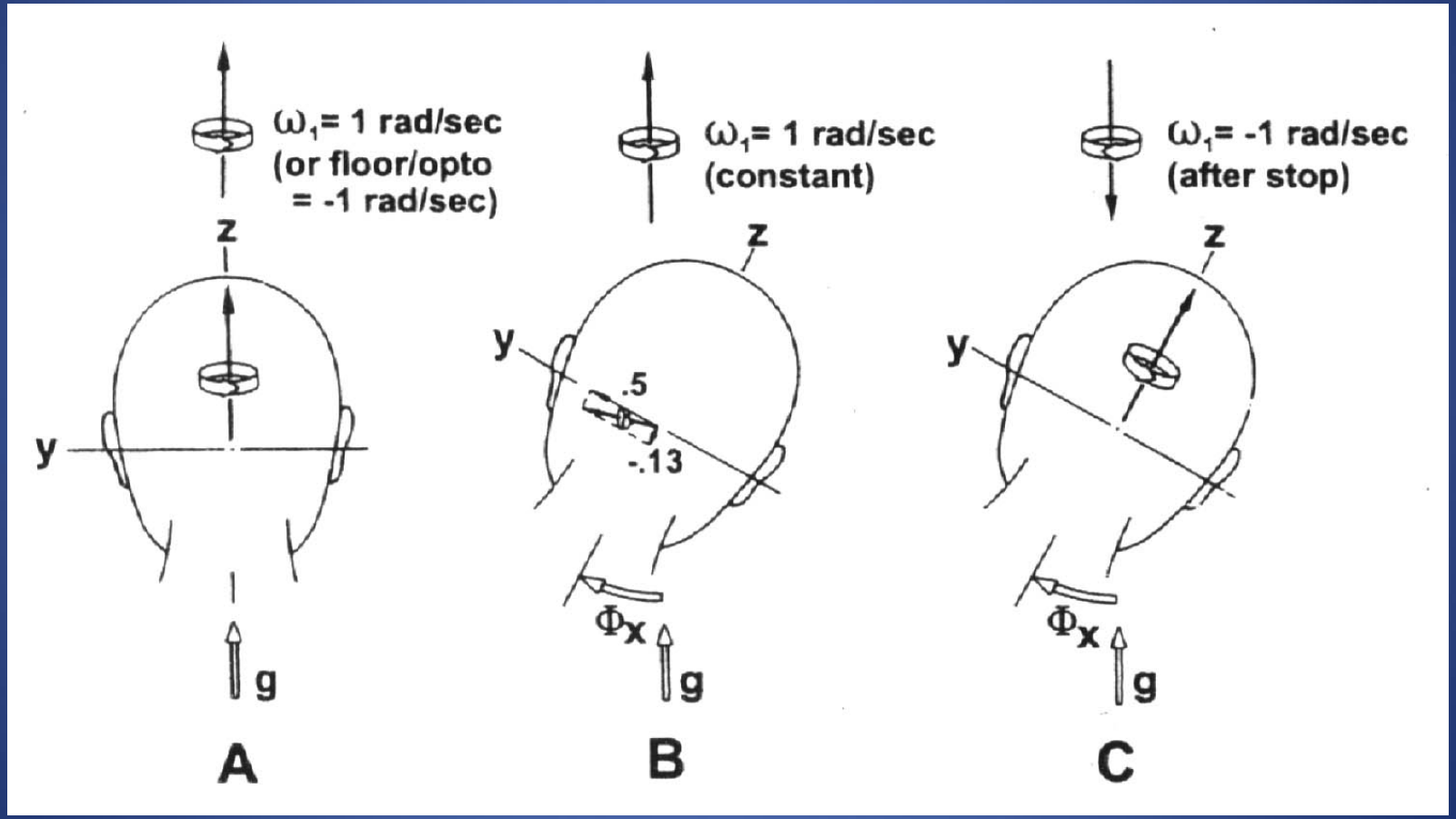
$$a_c = 2\,\omega \wedge V$$

$$F_c = m\,(2\,\omega \wedge V)$$

Coriolis effect


ω1
z
ω2
x
y
y
x
z
A
ω1
x
Φx
x
Φx = 90°
B
ω1
Φx
x
Φx = 30°
C

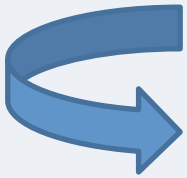
Coriolis and Purkinje effects



from Bles: Brain Res Bull, 47: 543-9, 1998

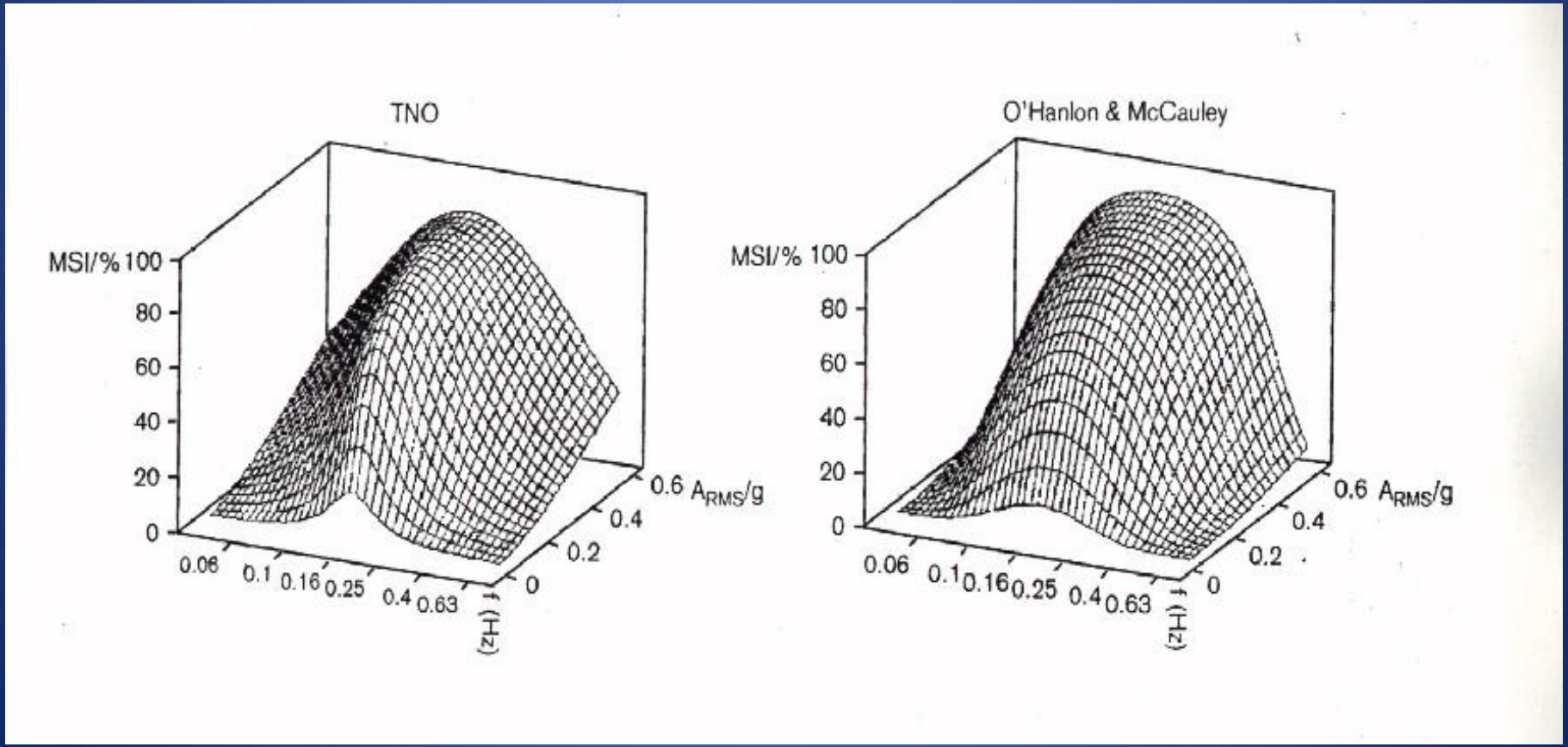
oculomotor aspects of Coriolis' phenomenon

VOR during Coriolis' stimulation

Chair rotation	Ny direction (tilt forward)	Ny direction (back to upright)
Clock-wise		
Anti-clock-wise		

from Bianca, 2015

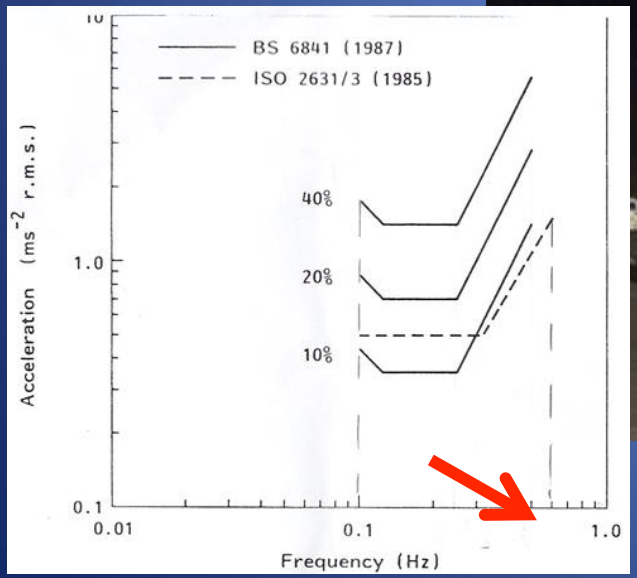
O'Hanlon & Mc Cauley
vs.
TNO data



Motion Sickness Dose Value

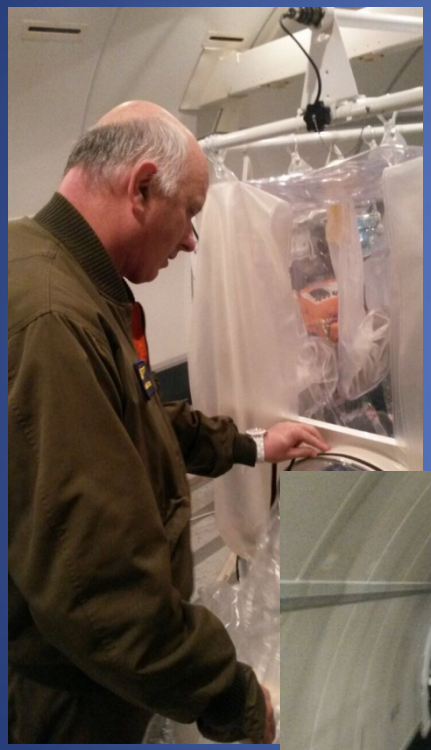
$$MSDV_Z = (a^2\ t)^{1/2}$$

motion sickness risk in ATI



from Lucertini et al., AMHP 2016

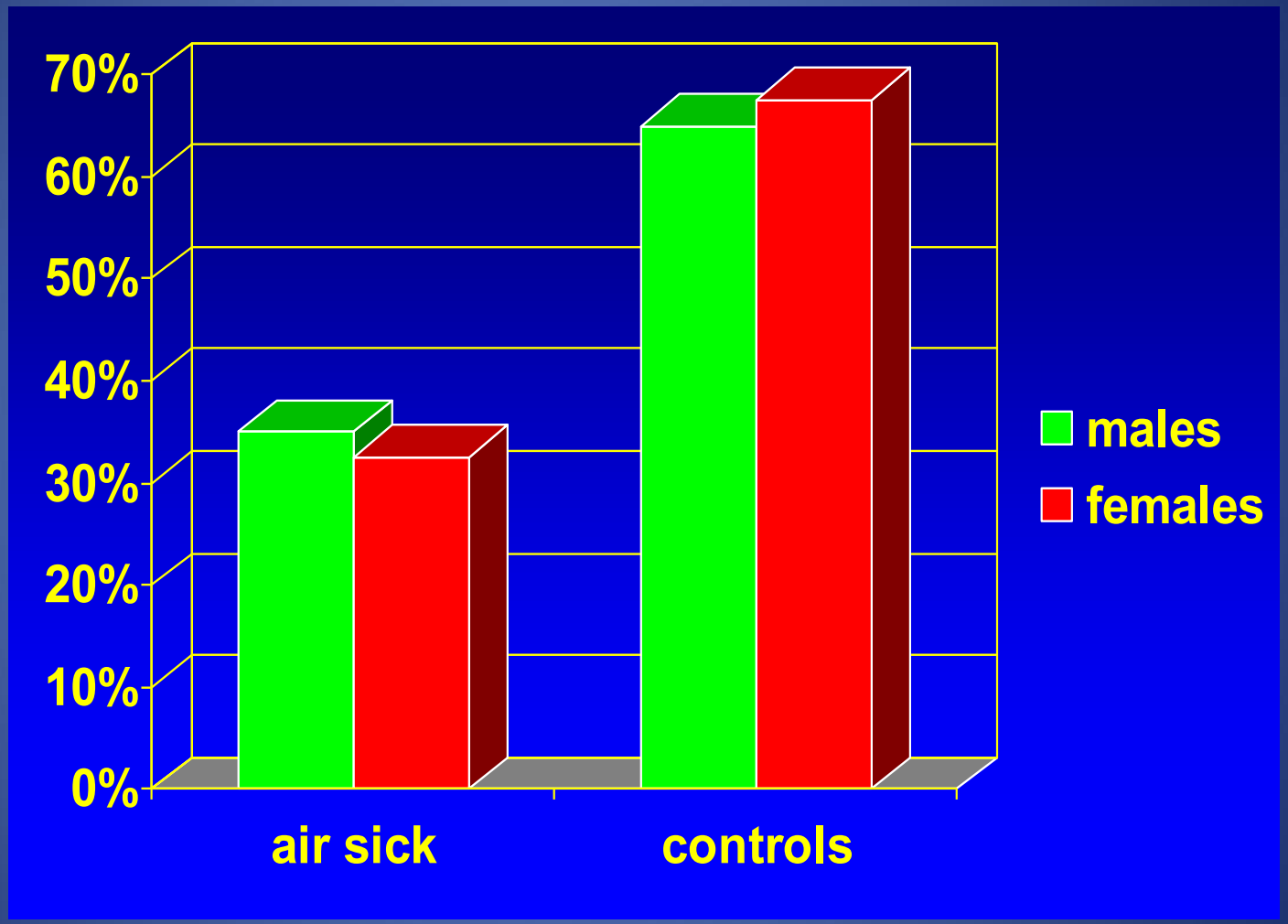
preliminary investigation



Subjective MS parameters

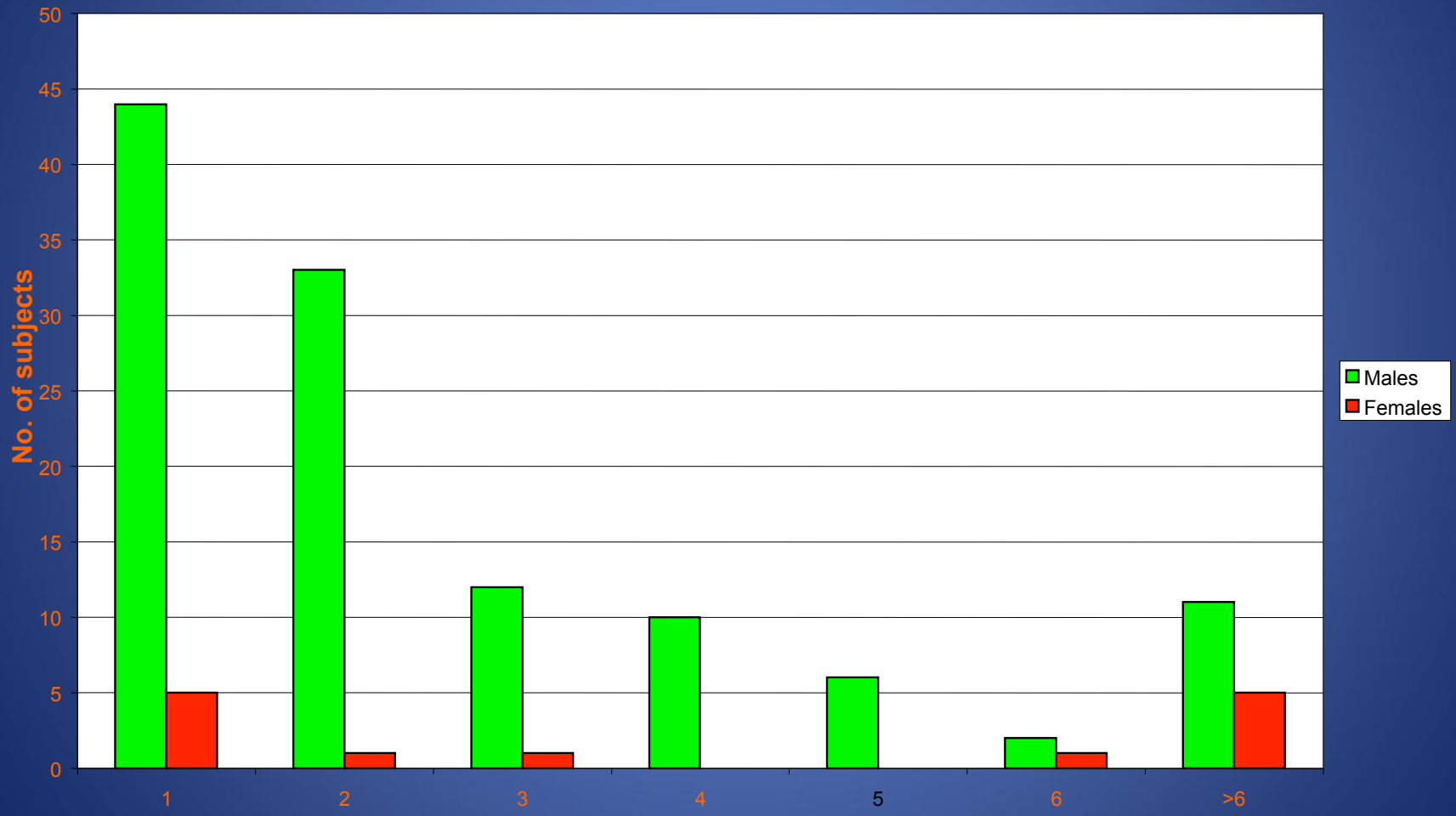
- Sensitivity
- Adaptation
- Retentivity

AS incidence according to gender



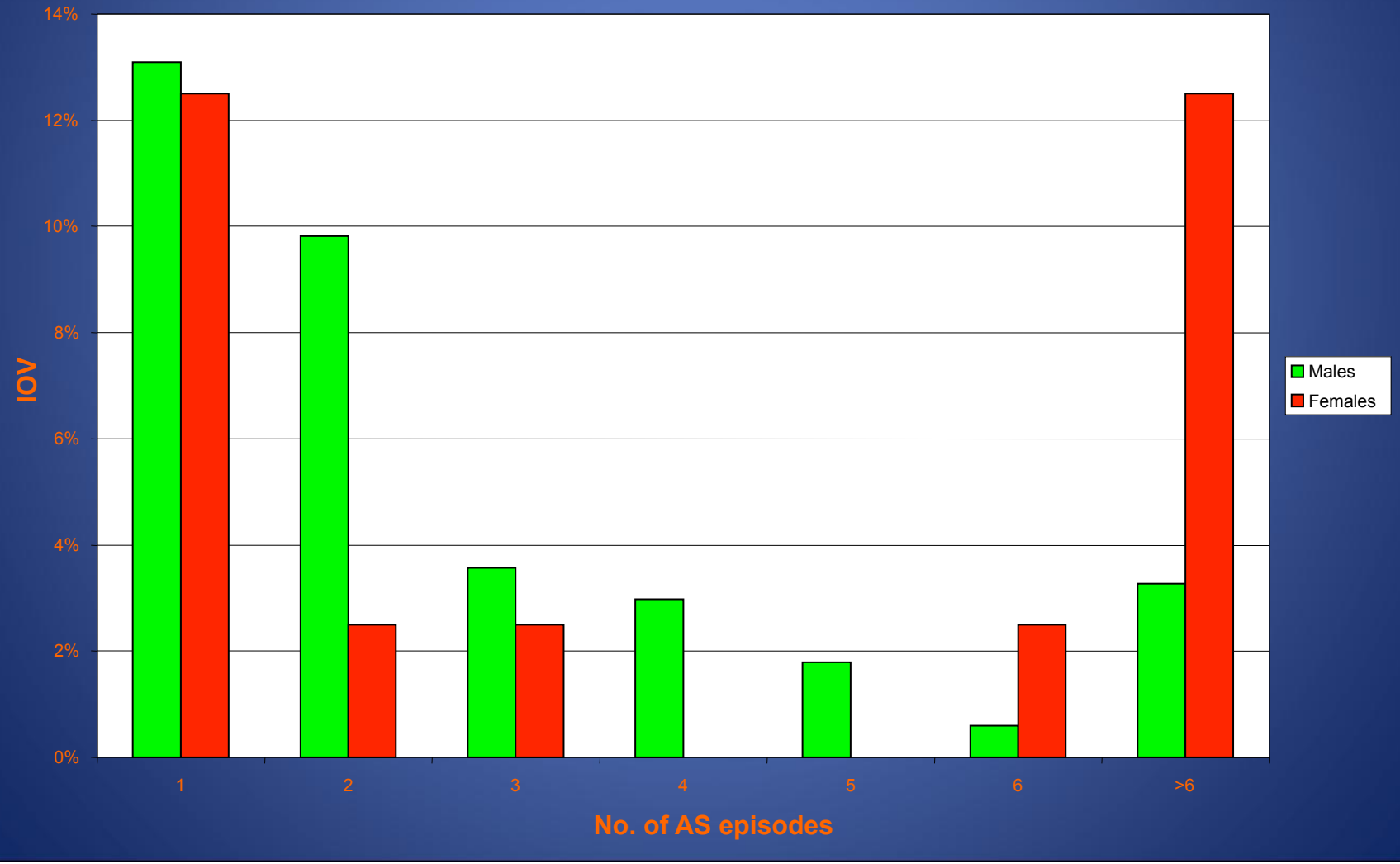
from Lucertini et al: ASEM 79: 677-84, 2008

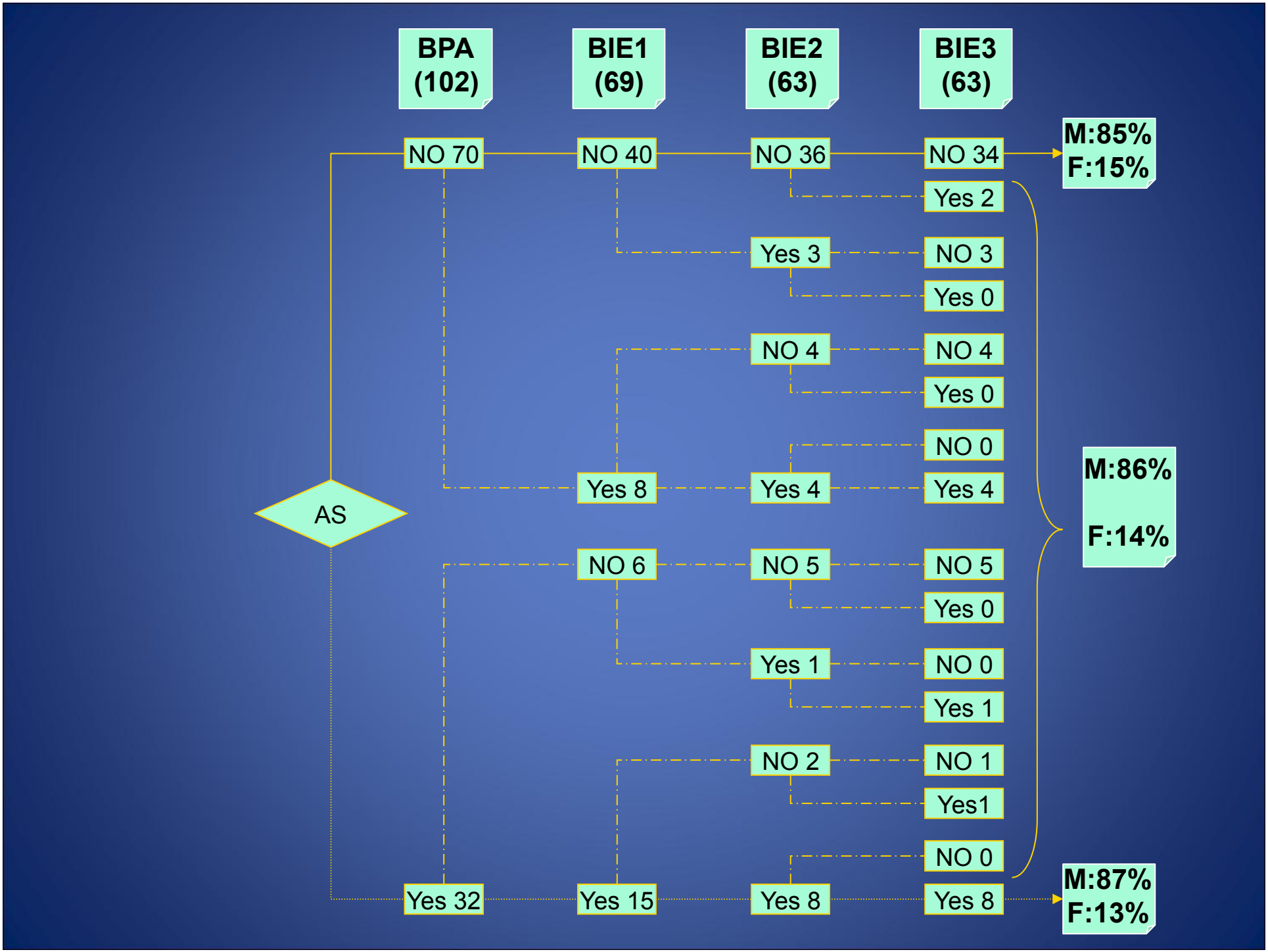
AS incidence



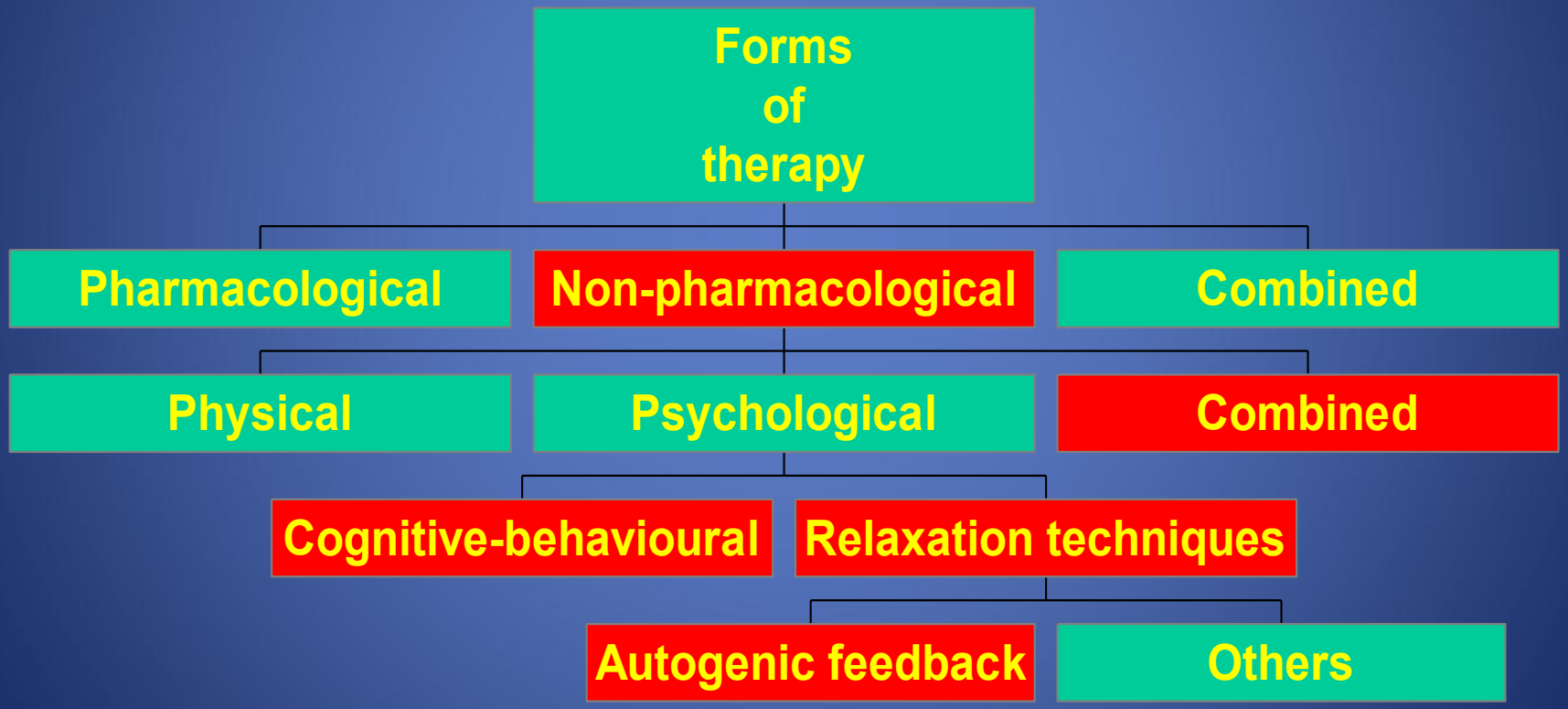
from Lucertini et al. (ASEM 2008)

Gender differences in AS onset




BPA (102)
BIE1 (69)
BIE2 (63)
BIE3 (63)
NO 70
NO 40
NO 36
NO 34
M:85%
F:15%
Yes 2
Yes 3
NO 3
Yes 0
NO 4
NO 4
Yes 0
NO 0
AS
Yes 8
Yes 4
Yes 4
M:86%
F:14%
NO 6
NO 5
NO 5
Yes 0
Yes 1
NO 0
Yes 1
NO 2
NO 1
Yes1
NO 0
Yes 32
Yes 15
Yes 8
Yes 8
M:87%
F:13%

MS treatment or prevention



Pharmacological approach

- Antimuscarinics
- Antihistamines
- Sympathomimetics
- Calcium antagonists
- Various combinations
- Homeopathics
- Others

Three general considerations

1 Dosing after the onset of symptoms is rarely beneficial

2 Scopolamine (oral, parenteral or transdermal) is the most effective drug

3 Sedation is a common side effect

Scopolamine (l-hyoscine)
ACh blocker

- Dosage: oral: 0.3-0.6 mg
  i.m.: 0.1 mg
  transdermal: 0.5 mg/72 hrs
- Duration (oral and i.m.): about 4 hrs
- Hepatic metabolism
- Side effects: drowsiness, dry mouth, skin and respiratory tract, blurred vision (mydriasis)
- Contraindications: glaucoma, prostatic enlargement, children and elderlies
- Habituation can be significantly prolonged

promethazine

- Dosage: oral and i.m. = 25 mg
- Duration: about 4-6 hrs (after 2-3 hrs)
- Hepatic metabolism
- Side effects: drowsiness, diminished alertness and slowed reaction times; CNS and visual symptoms; gastro-intestinal disorders (drug should be assumed with meals)

dimenhydrinate

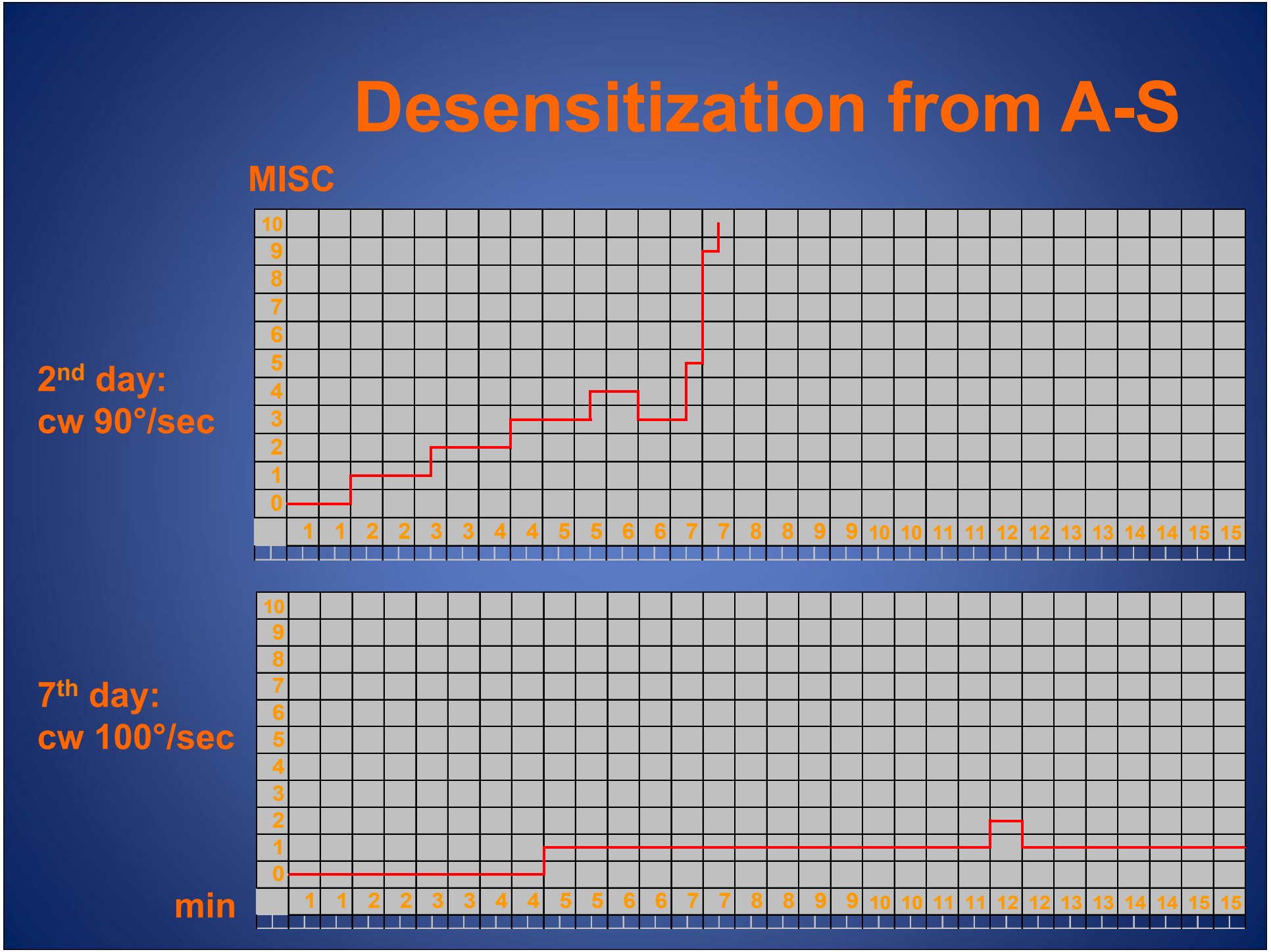
- Dosage: oral and i.m.: 50 mg
  chewing gums: 20 mg
- Duration: 4-6 hrs
- Hepatic metabolism
- Side effects: minor drowsiness

ItAF rehabilitation program (2 weeks)

- 1st day: preliminary evaluation and CST;
- 2nd - 9th day: progressive physical approach (i.e. rotatory chair, vertical accelerator, Diso);
- 10th day: final evaluation and CST.

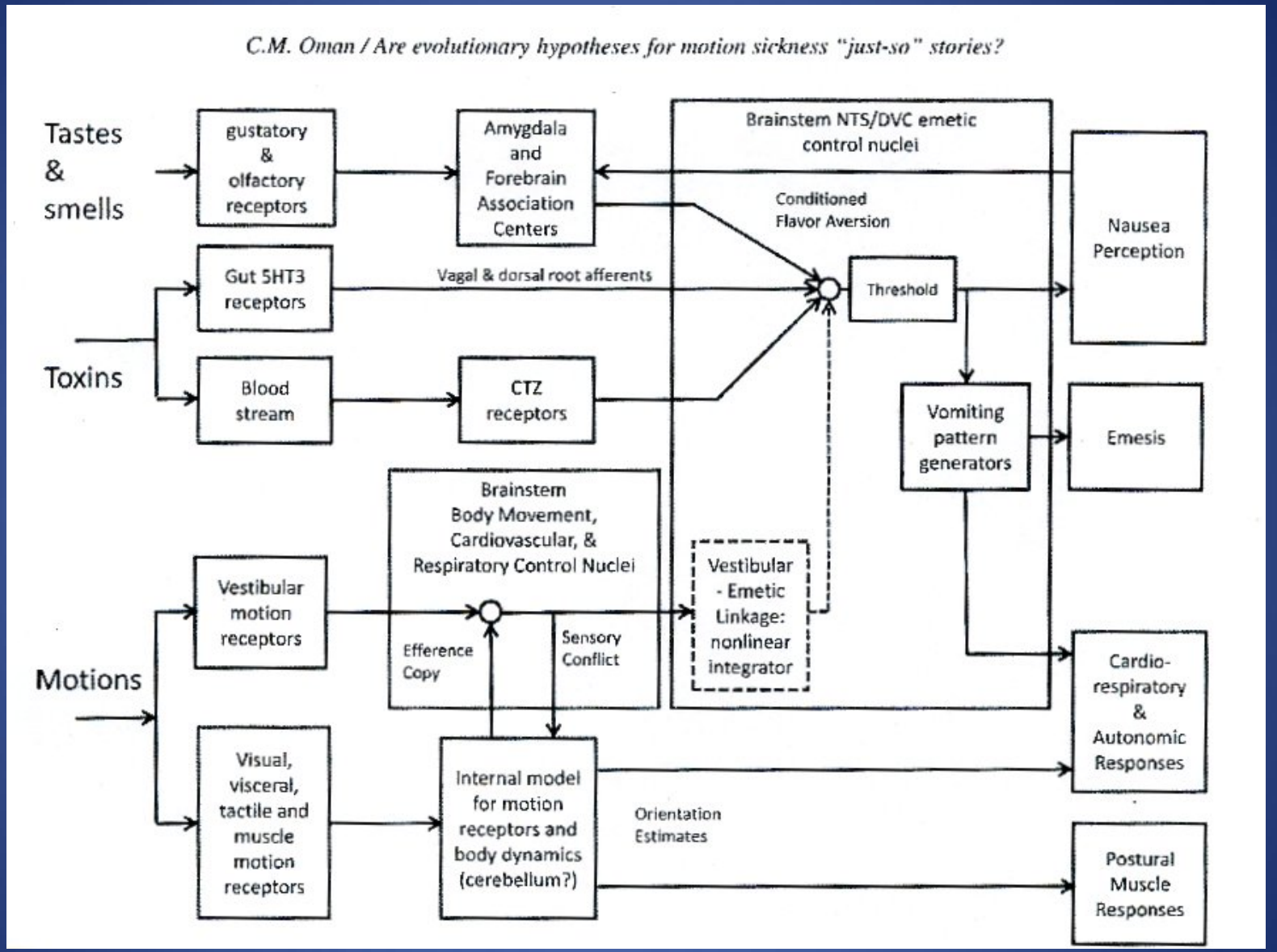
spatial orientation lab

Desensitization from A-S

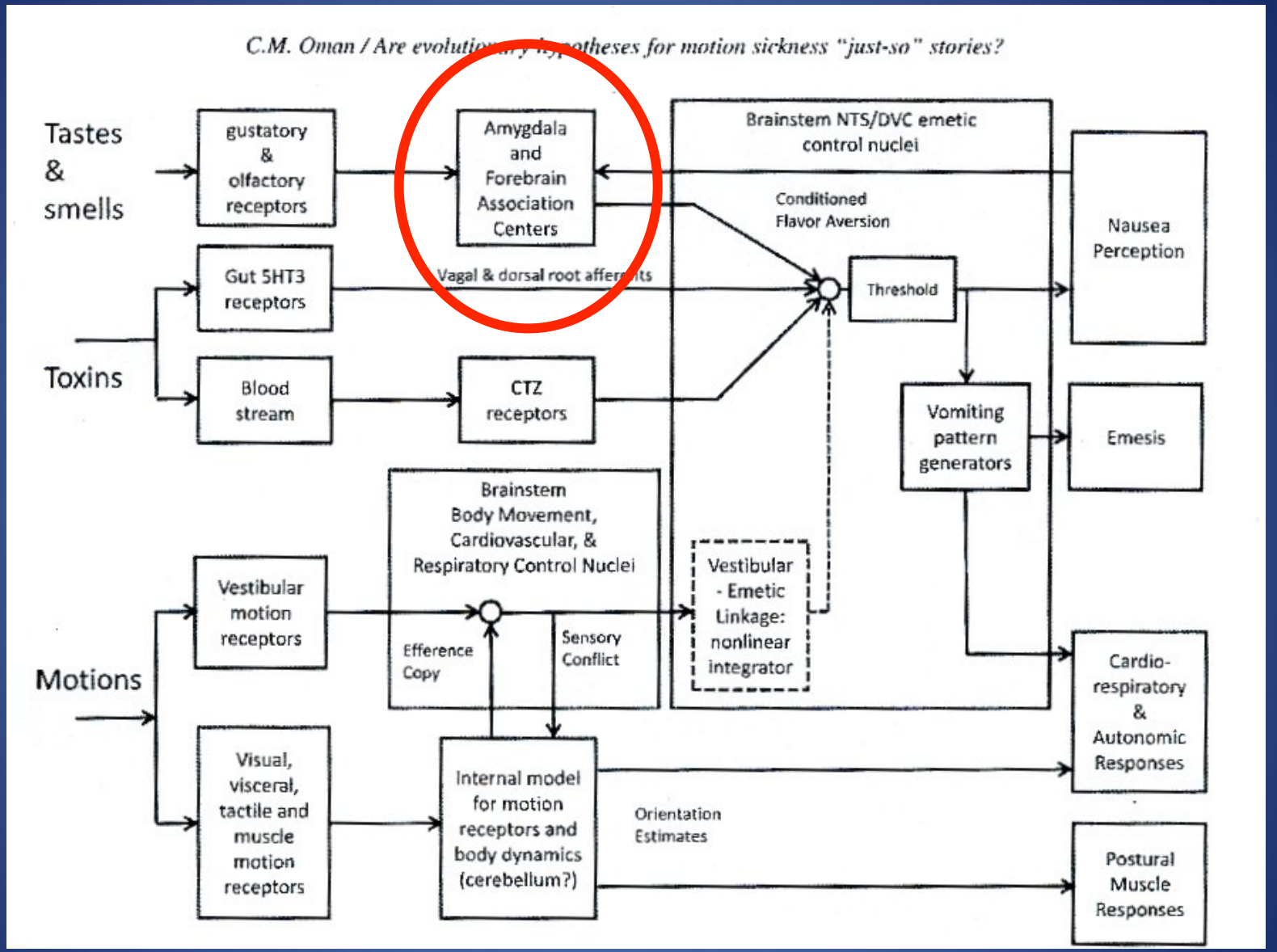


Some data on AS desensitization

Author	Year	No. of Sub.s	Duration (weeks)	Flight	Psychol. Approach	Success Rate
Levy et al.	1981	20	2	Y (5 m.)	Y	85%
Giles & Lochridge	1985	37	1	N	Y	95%
Stott	1990	66	4	Y (15 m.)	N	79%
Stott	1990	17	4	N	N	94%
Bles et al.	1994	5	2	N	N	100%
Lucertini & Lugli	2003	16	2	N	Y	88%



from Oman, 2012



from Oman, 2012

More specific ItAF data

Aircrew category	Number of subjects	Healed in laboratory	Healed in Flight (short term)	Healed in Flight (long term)
Pilots	3	3 (100%)	3 (100%)	3/3 (100%)
Student pilots	12	10 (83%)*	10 (83%)*	5/6 (83%)
Navigators	2	2 (100%)	2 (100%)	1/2 (50%)
Total	17	15 (88%)*	15 (88%)*	9/11 (82%)

* Only 9 out of 10 student pilots in column no.3 are part of the sample indicated in column no.4. This finding can also be observed in the total data (last row).

(Lucertini & Lugli, Acta ORL Ital 2004)

long term follow up (avg. 8 yrs)

	Treated	Controls
No. of subjects	20	65
DO	3 (15%)	9 (14%)
TARF	4 (20%)	23 (35%)
TTB	10 (50%)	22 (34%)
Helo	3 (15%)	11 (17%)

from Lucertini et al., ASEM 2013

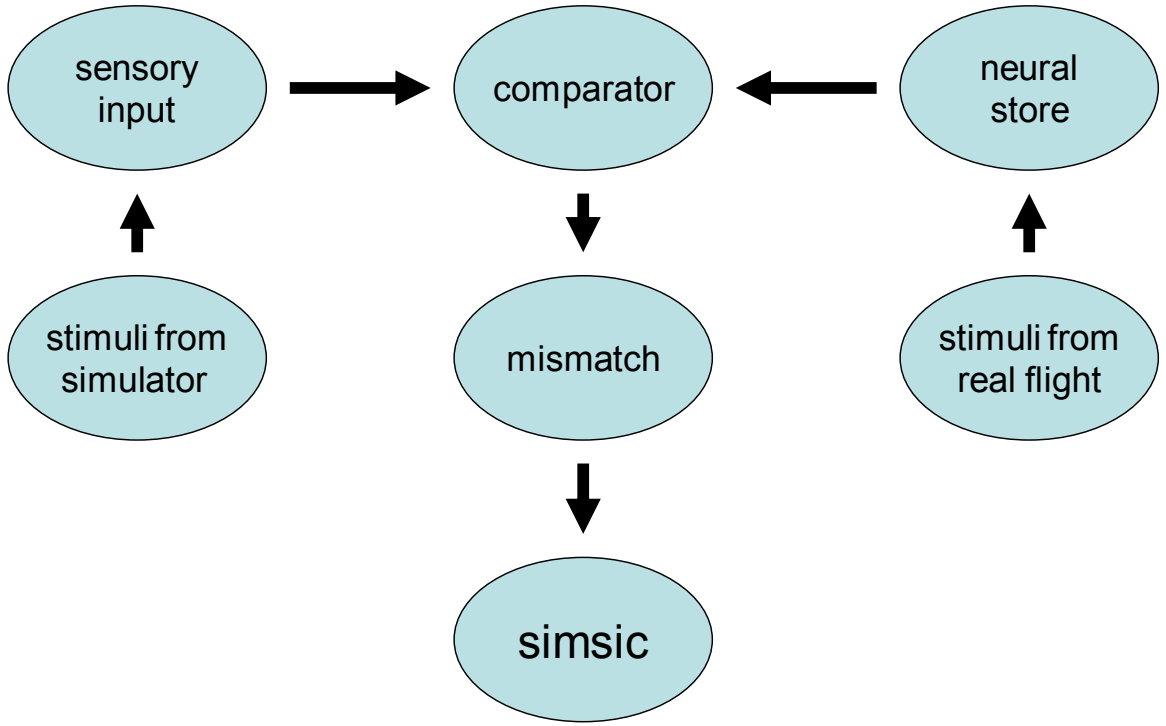
Most of dropouts from the flight training course are observed within the first post-rehabilitation year.

Lucertini et al, ASEM 2013

Virtual Reality Sickness

Clinical syndrome similar in some aspects to motion sickness, which only occurs when a specific environment is simulated (e.g. in flight simulators), but not in the real situation.

Simulator sickness

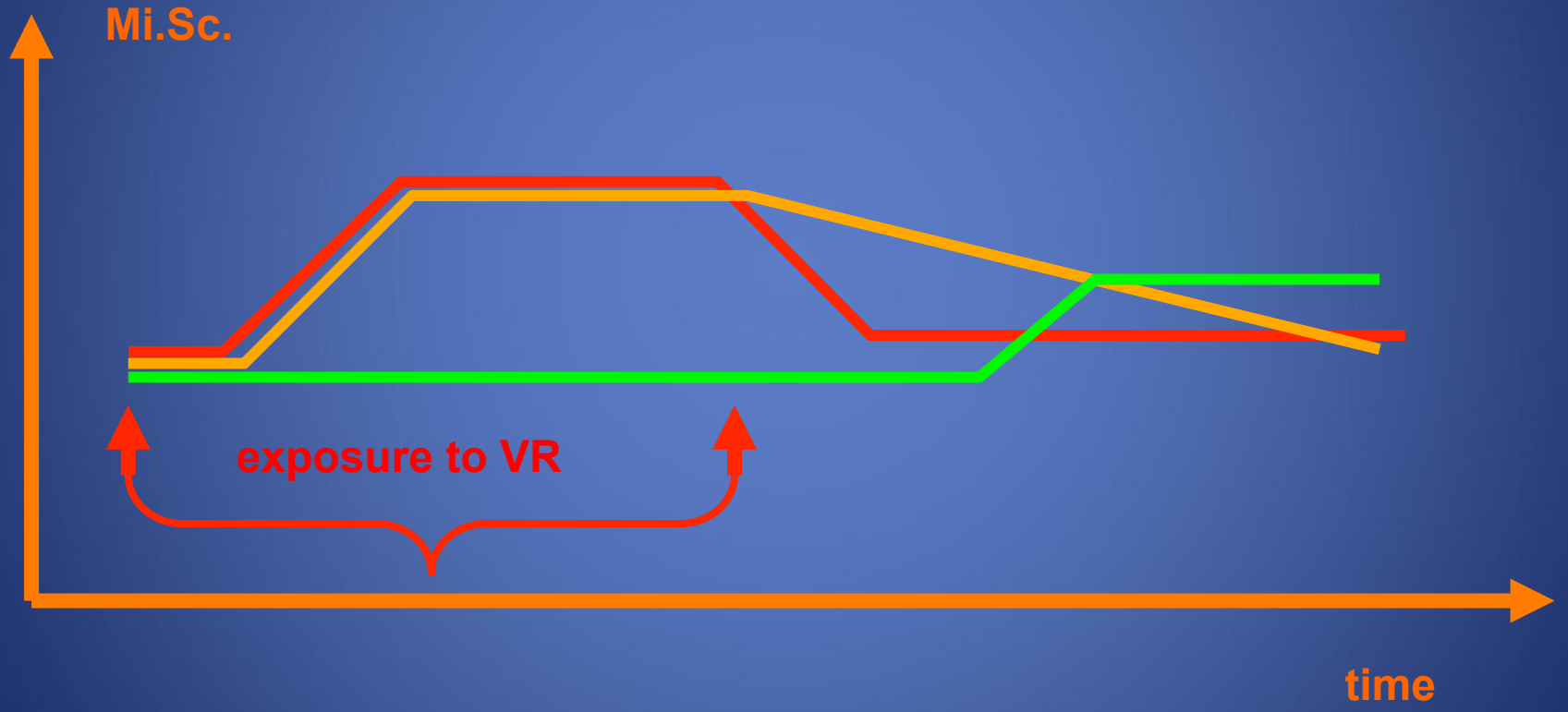


(from Lucertini, IJASM 2011)

Simulator sickness

- It is typical of expert pilots, who easily detect discrepancies between real flight and simulation.
- It is typical of pilots unskilled in simulator training.
- It is in part different from motion sickness (less nausea, more visual disorders)
- Both fixed- and motion-base simulators.
- It can last several hours or can follow the simulator hops.

Time course of SS symptoms



The Pensacola Simulator Sickness Questionnaire (SSQ)

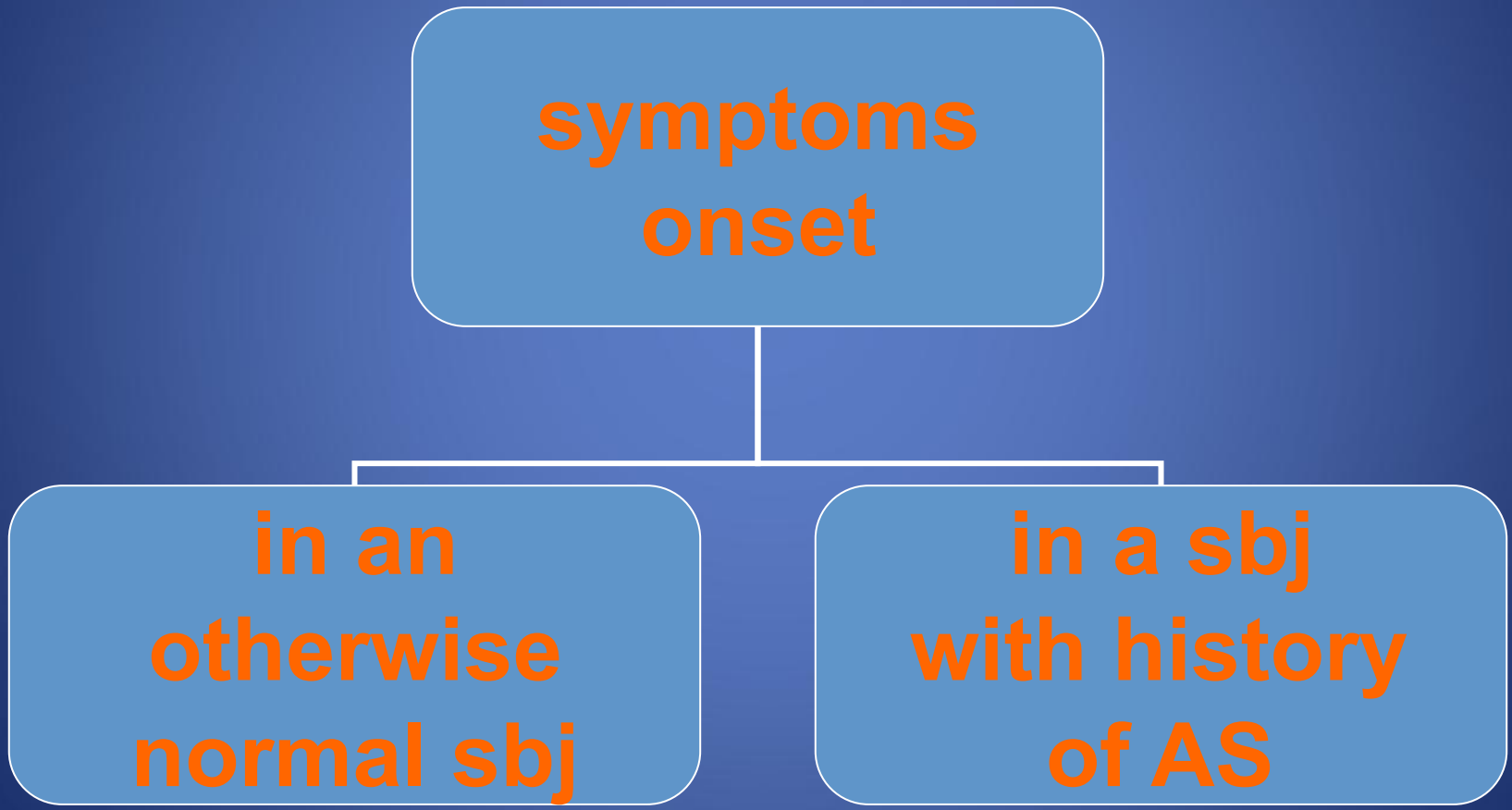
- General discomfort
- Increased salivation
- Sweating
- Nausea
- Diff. concentrating
- Stomach awareness
- Burping
- Fatigue
- Headache
- Eyestrain
- Diff. focusing
- Blurred vision
- Fullness of head
- Dizzy-eyes open
- Dizzy-eyes closed
- Vertigo

(Kennedy et al. 1993)

N - O - D


questions?
Meridiana
airberlin
Danke. Und was stört Sie konkret?
Did something disagree with you?
Delta
Occupied
Occupé
Besetzt
Ocupado
Occupato
AIR CANADA
PREISE DER KONKURRENZ
TURBULENZEN
KEEP CALM
BREATHE
Alitalia
ICELANDAIR
Airsickness Bag
Cartucho de mareo
CUBANA
CZECH AIRLINES
Air Sickness Bag
ASSISTENZA DI BORDO
Take Care
London
New York
paris
Toronto
Tokyo
Jakarta
Amsterdam

Simsic


symptoms onset
in an otherwise normal sbj
in a sbj with history of AS

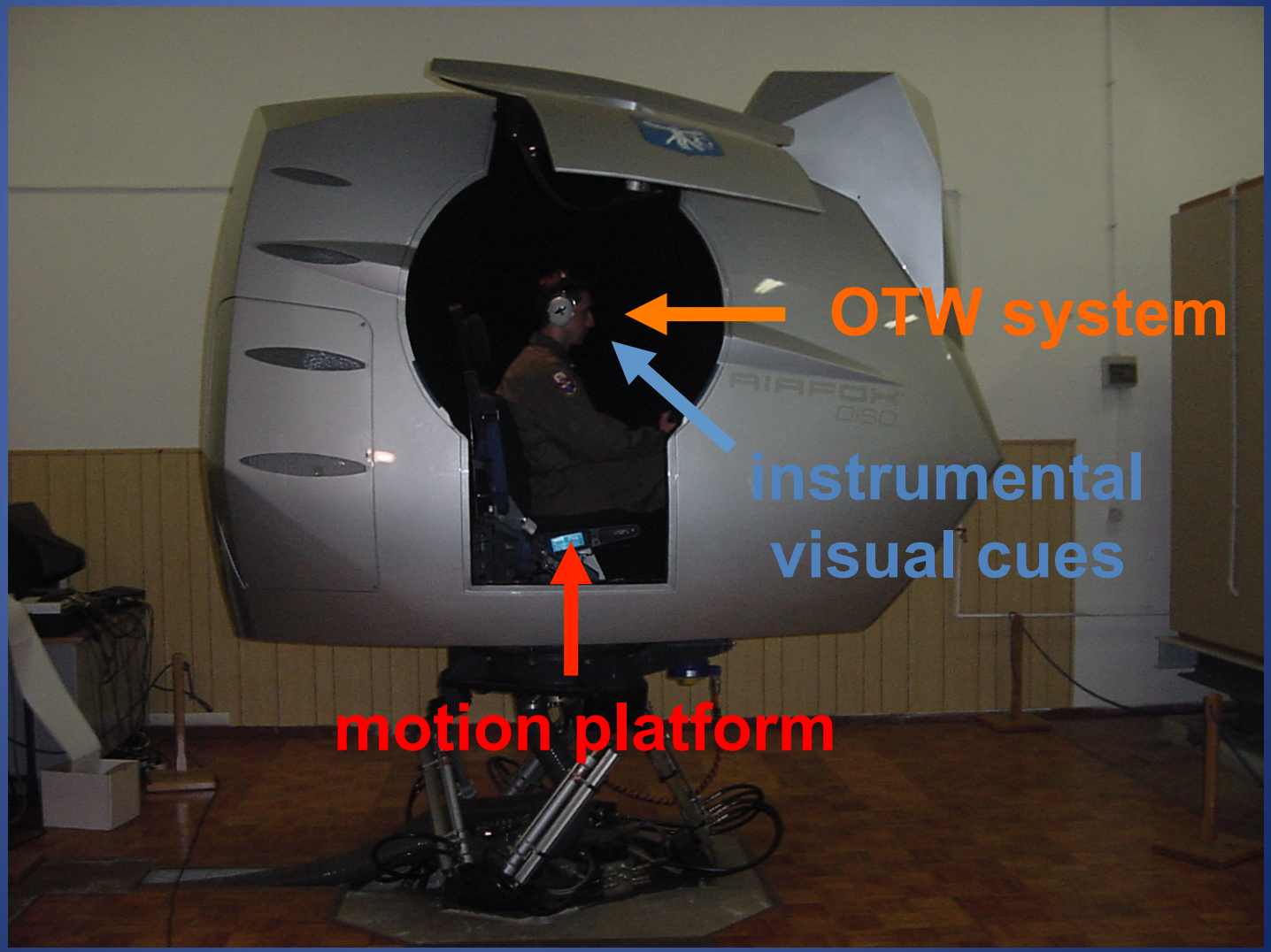
First literature finding

Havron MD, Butler LF: Evaluation of training effectiveness of the 2FH2 helicopter flight trainer research tool. Port Washington, New York: Naval Training Device Center; Technical report NAVTRADEVCEN 1915-00-1, 1957.

ITAF SD demonstrator (1950s)

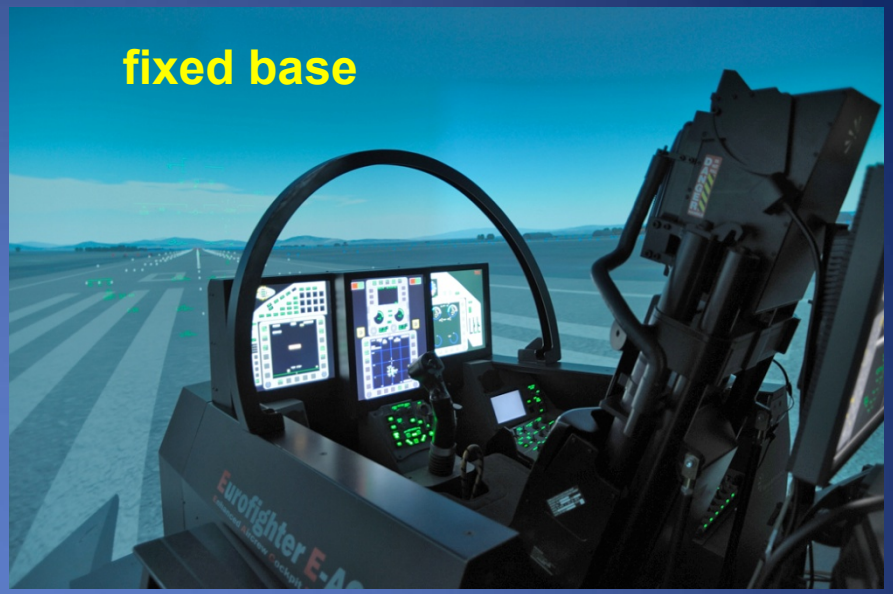
Sensory inputs

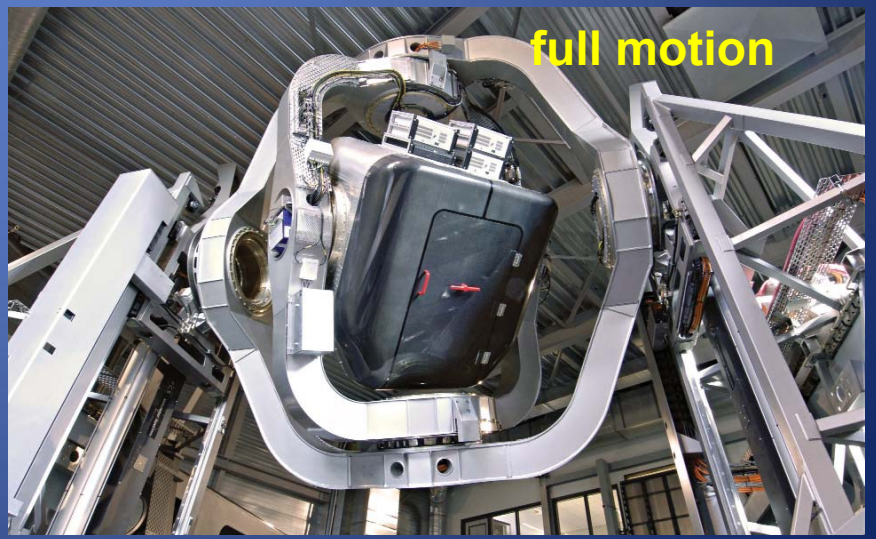
Sensory inputs

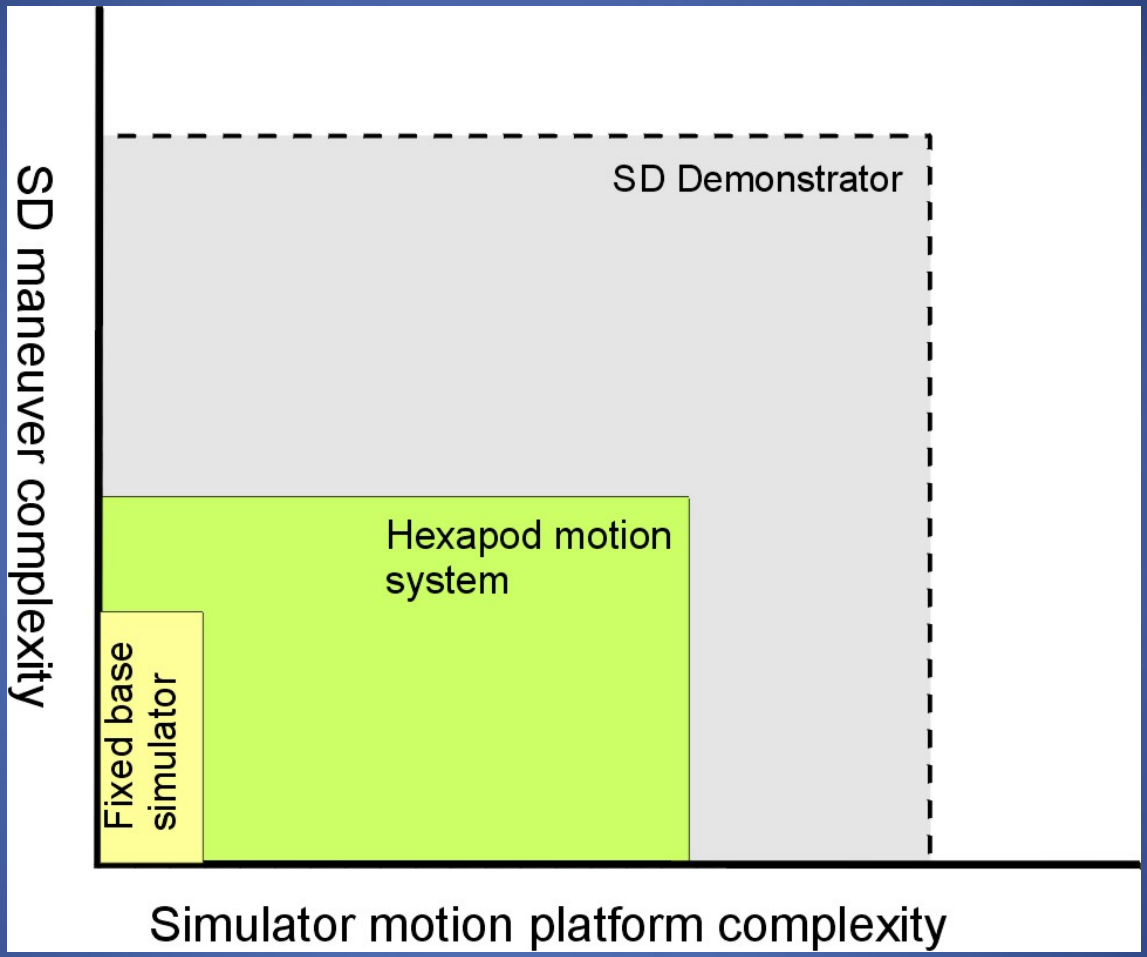


Desdemona at the TNO

Types of flight simulators (according to motion parameters)







(from the RTO-TR-HFM-118, 2008)

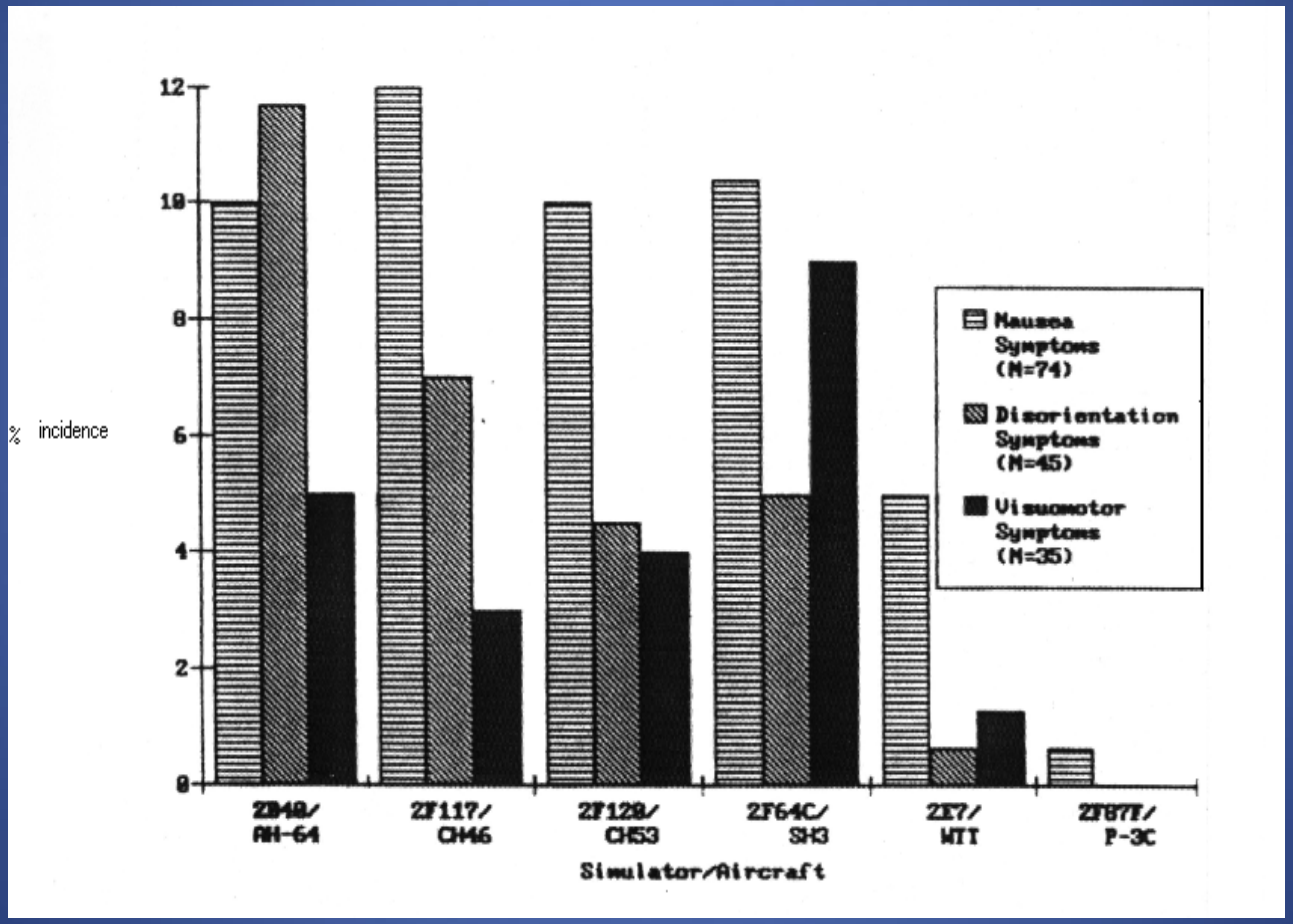
Incidence:

- 78% in 1958 (Miller & Goodson).
- 10% of pilots experience some form of nausea in simulators, and 25% complain of eyestrain (Money 1991).
- 48% helo vs 32% fixed-wing (Baltzley et al. 1989)
- 47% (>1500 fl hrs) vs 18% in the rest (McGuinness et al 1981).
- Other studies quantify the simsic incidence in about 10% of individuals undergoing standard simulator training

ITAF/SPAF Eurofighter survey on SD

- 77% of subjects reported previous SD episodes on aircrafts different from EFA
- 38% also reported SD episodes on EFA, which implied the use of the "disorientation recovery function (DRF)" in one case from the Italian sample (10% within this subsample)
- 8% of pilots reported simsic after ground based training
- No significant relationship was reported between SD and other potentially contributing factors (A-LOC, unusual attitudes, etc..)
- Mild differences were detected between the Italian and the Spanish subsample (e.g. SD episodes before

Simsic (> 1h) in different flight simulators



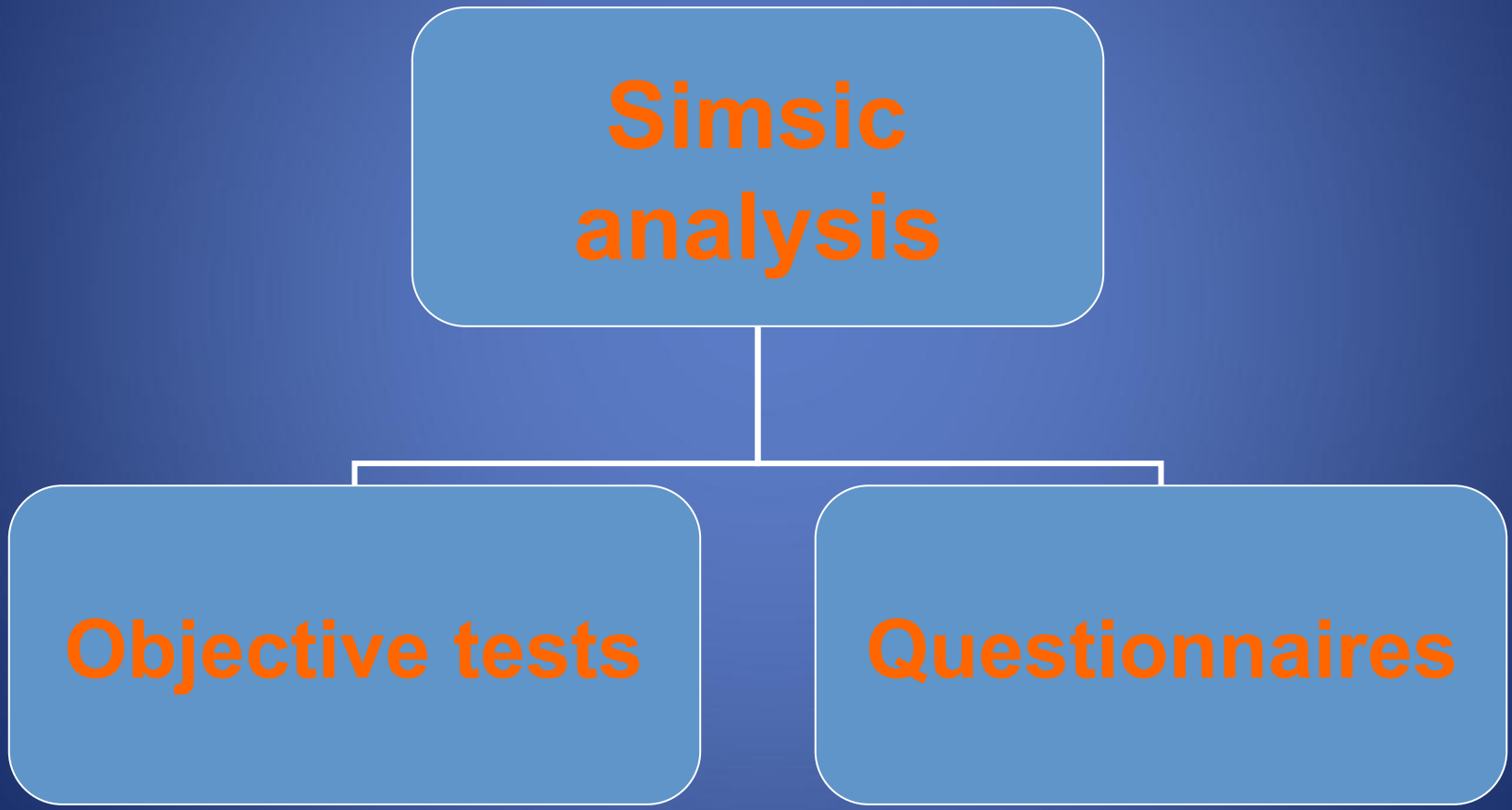
(from Baltzley et al 1989)

Symptom duration

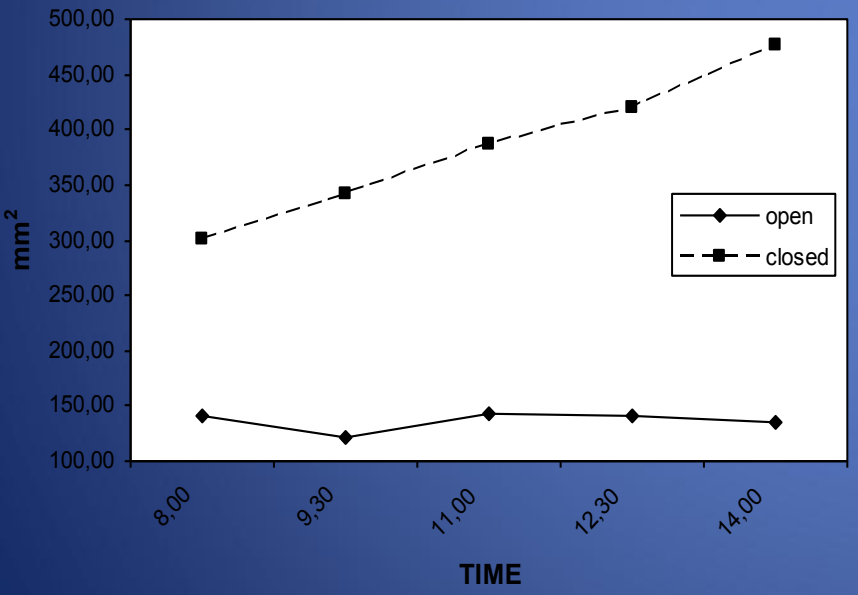
	0.5 – 1 h	1.1 – 6 h	>6 h	total
Visual	11.0%	6.7%	2.7%	20.4%
Vestibular	16.0%	7.0%	5.4%	28.4%
Vagal	31.5%	14.0%	5.7%	51.2%
total	58.5%	27.7%	13.8%	100%

(modified from Baltzley et al. 1989)

How can we diagnose SS ?



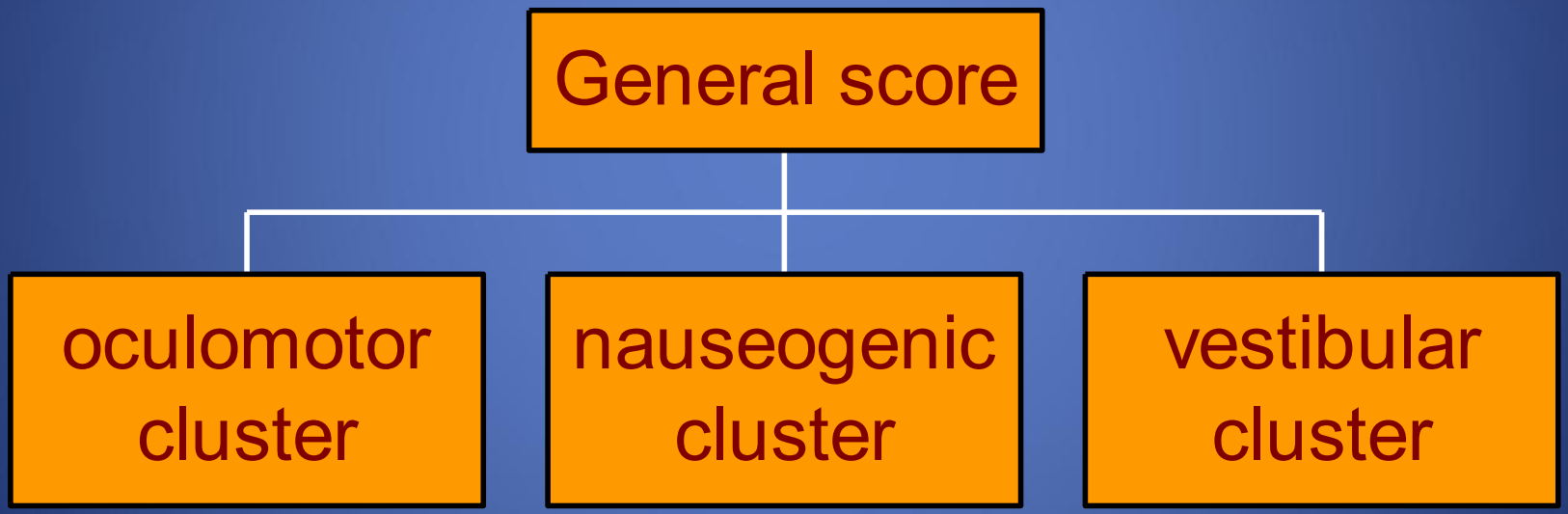
Surface of the ellipse under SD training and cinnarizine



(from Lucertini et al.: Physiol & Behav, 91: 180-90, 2007)

eye tracking

SSQ

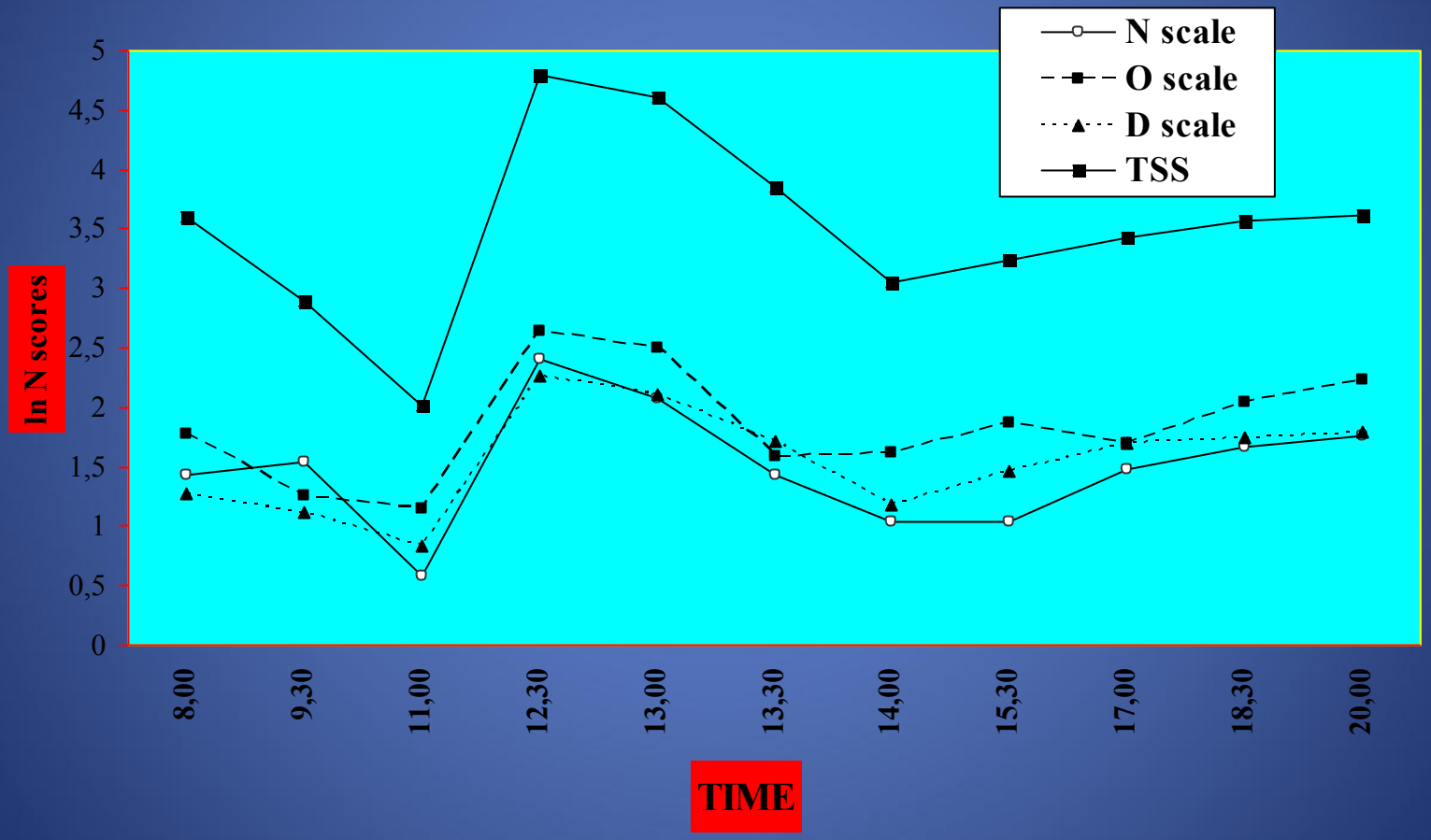

General score
oculomotor cluster
nauseogenic cluster
vestibular cluster

Asthenopia

Temporary visual weakness, often related to visually demanding tasks. Other non-visual symptoms may include nausea, migraine and/or dizziness. It is common in subjects operating on videoterminals, including those in flight simulators.

A horizontal FOV larger than 60° is usually required to evoke symptoms (Mooij, 1988).

SSQ variations before, during and after simulator rides



(Lucertini et al. 2007)

SSQ characteristics

- Lack of specific evaluation for drowsiness
- Does not evaluate performance
- Specific weight of single symptoms
- Some symptoms rarely occur
- It should be administered immediately after the simulator session, but not before

drowsiness

Epworth Sleepiness Scale

Name: _____

Date: _____

Your age: (Yr) _____ **Your sex:** ❑ Male ❑ Female

How likely are you to doze off or fall asleep in the situations described below, in contrast to feeling just tired?

This refers to your usual way of life in recent times.

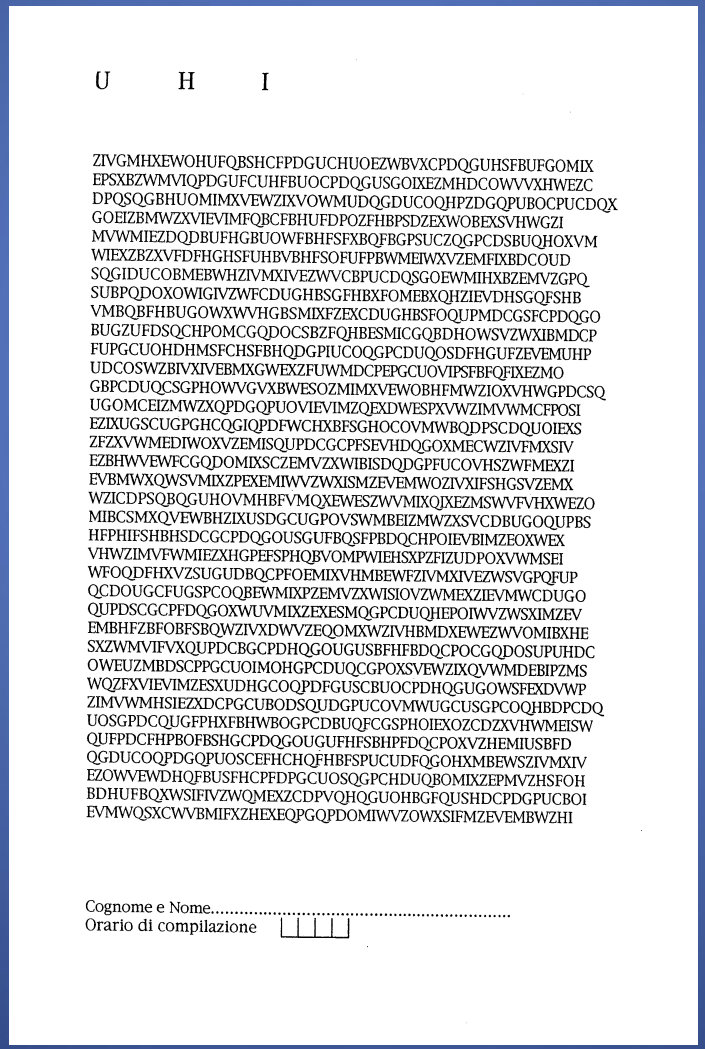
Even if you haven't done some of these things recently try to work out how they would have affected you.

Use the following scale to choose the most appropriate number for each situation:-

0 = would never doze
1 = Slight chance of dozing
2 = Moderate chance of dozing
3 = High chance of dozing

Situation	Chance of dozing
Sitting and reading	
Watching TV	
Sitting, inactive in a public place (e.g. a theatre or a meeting)	
As a passenger in a car for an hour without a break	
Lying down to rest in the afternoon when circumstances permit	
Sitting and talking to someone	
Sitting quietly after a lunch without alcohol	
In a car, while stopped for a few minutes in the traffic	
Total	

performance evaluation



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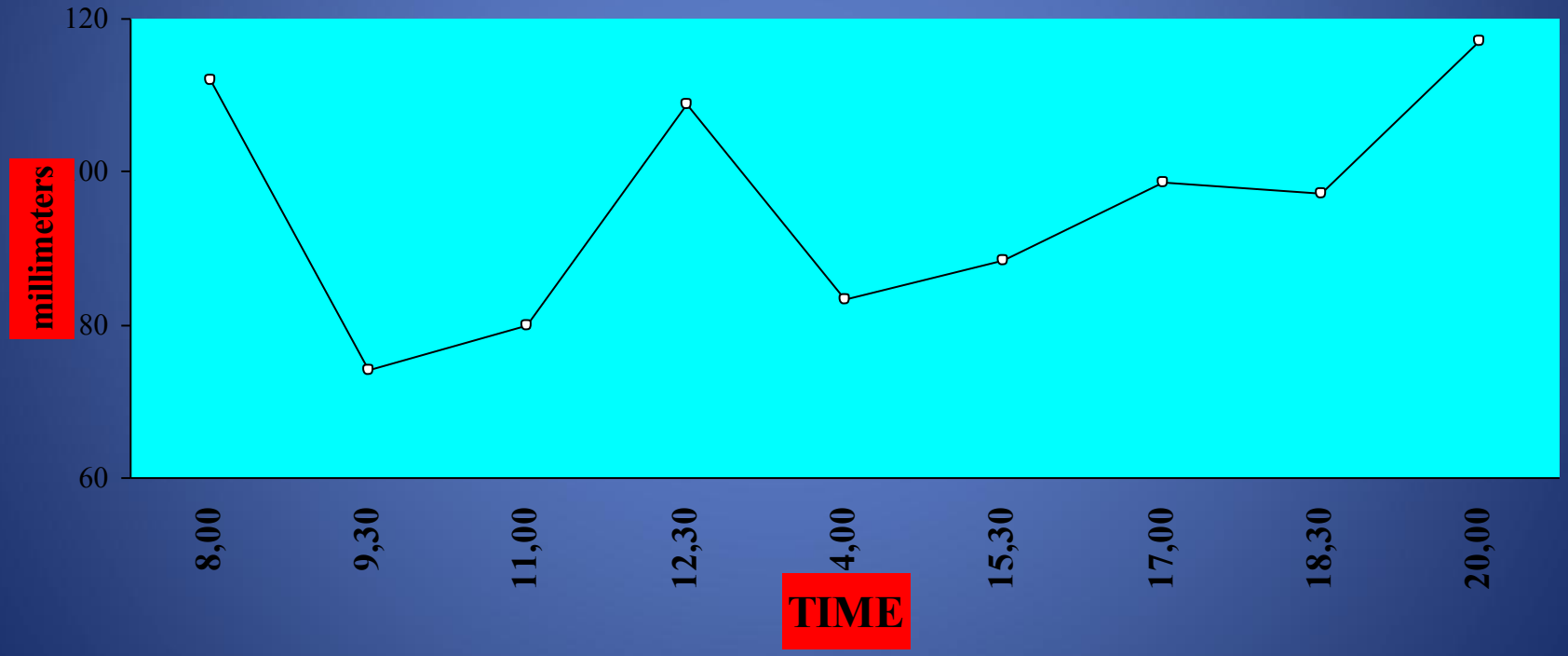
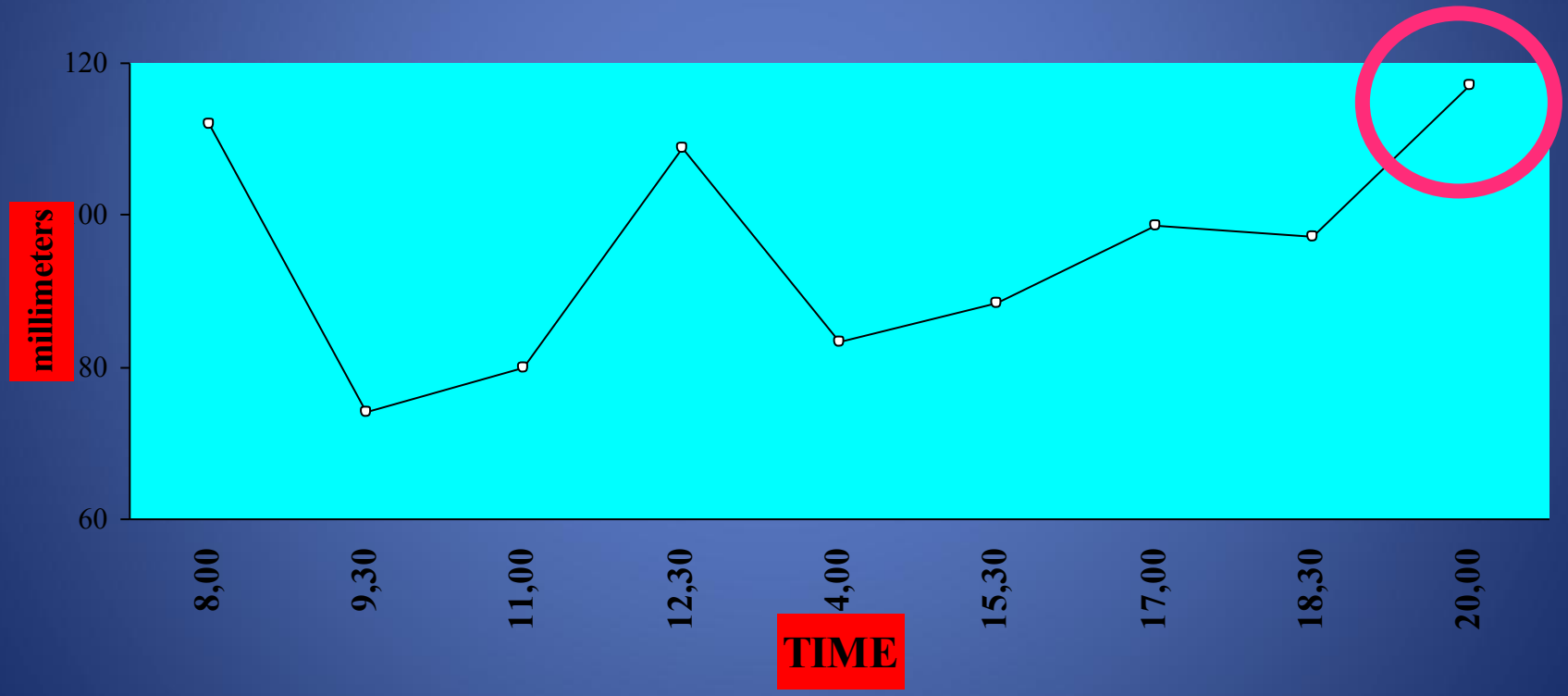
Cognome e Nome.....
Orario di compilazione ⌊⌊⌊⌊⌋

Time of day variation for sleepiness



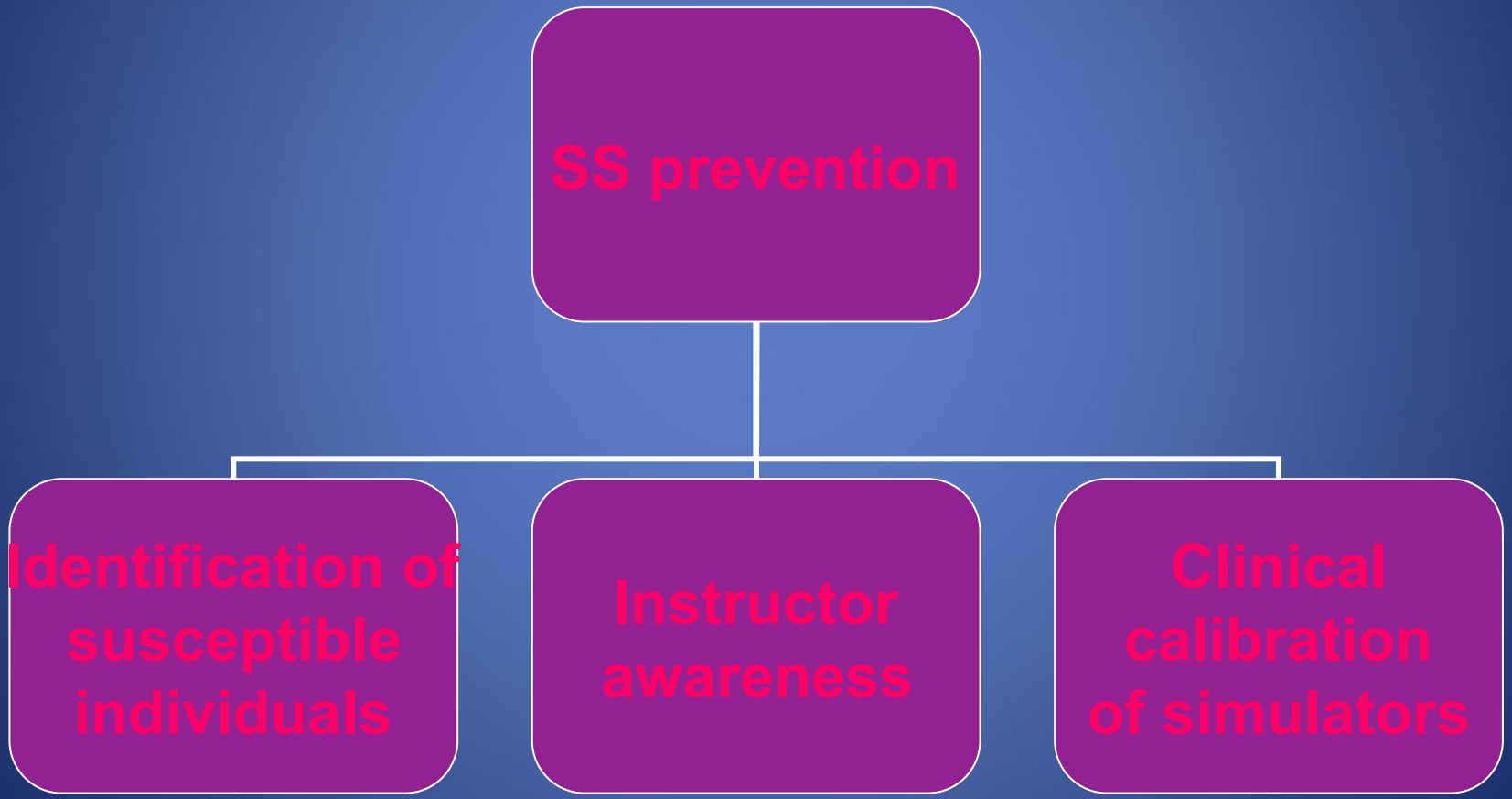
(from Lucertini et al: IRAFMS 2008)

Time of day variation for sleepiness

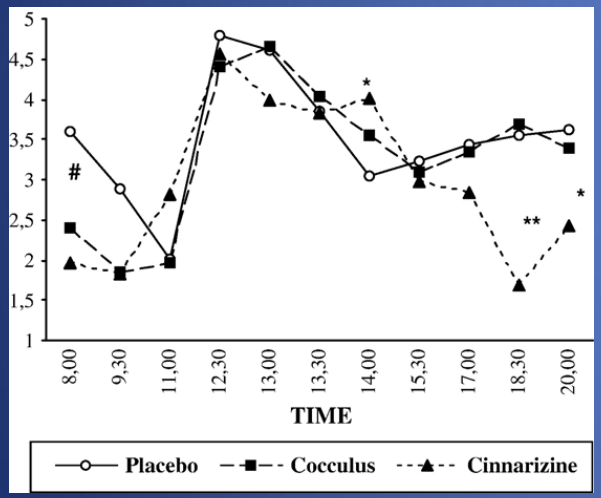


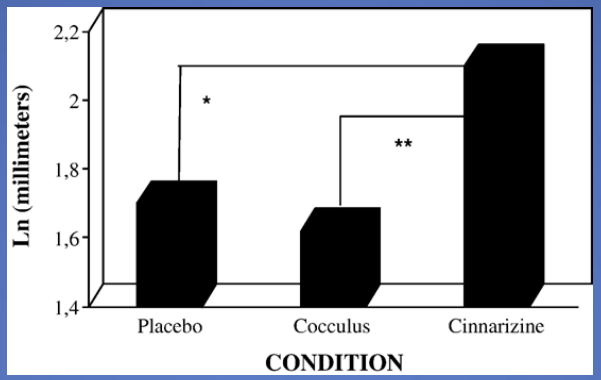
(from Lucertini et al: IRAFMS 2008)

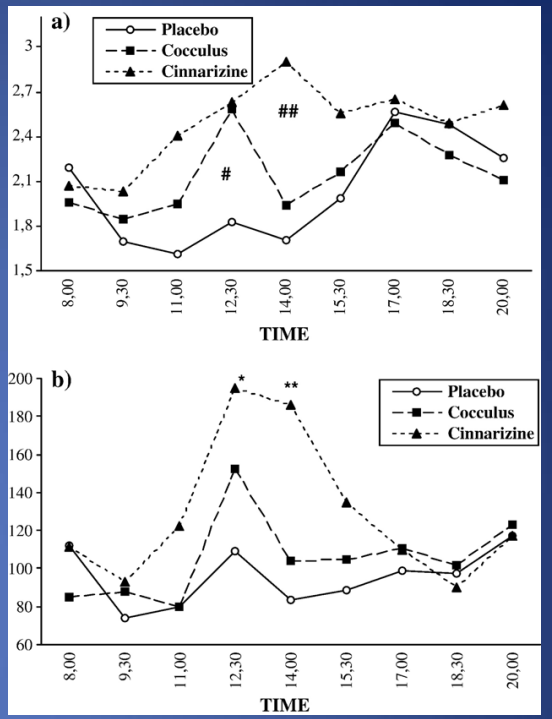
How to deal with SS

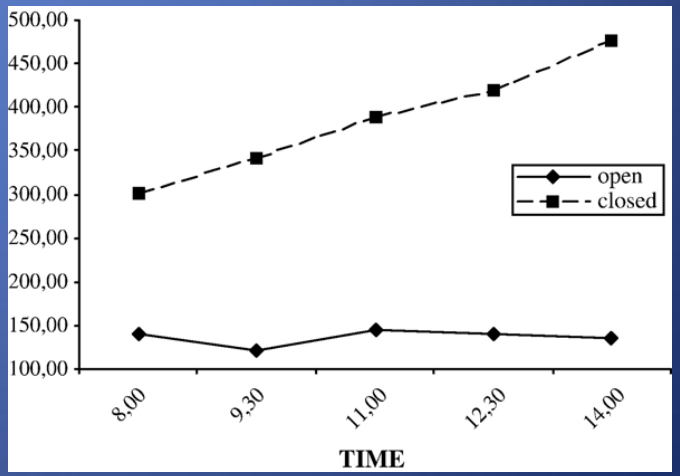


Cinnarizine 30 mg







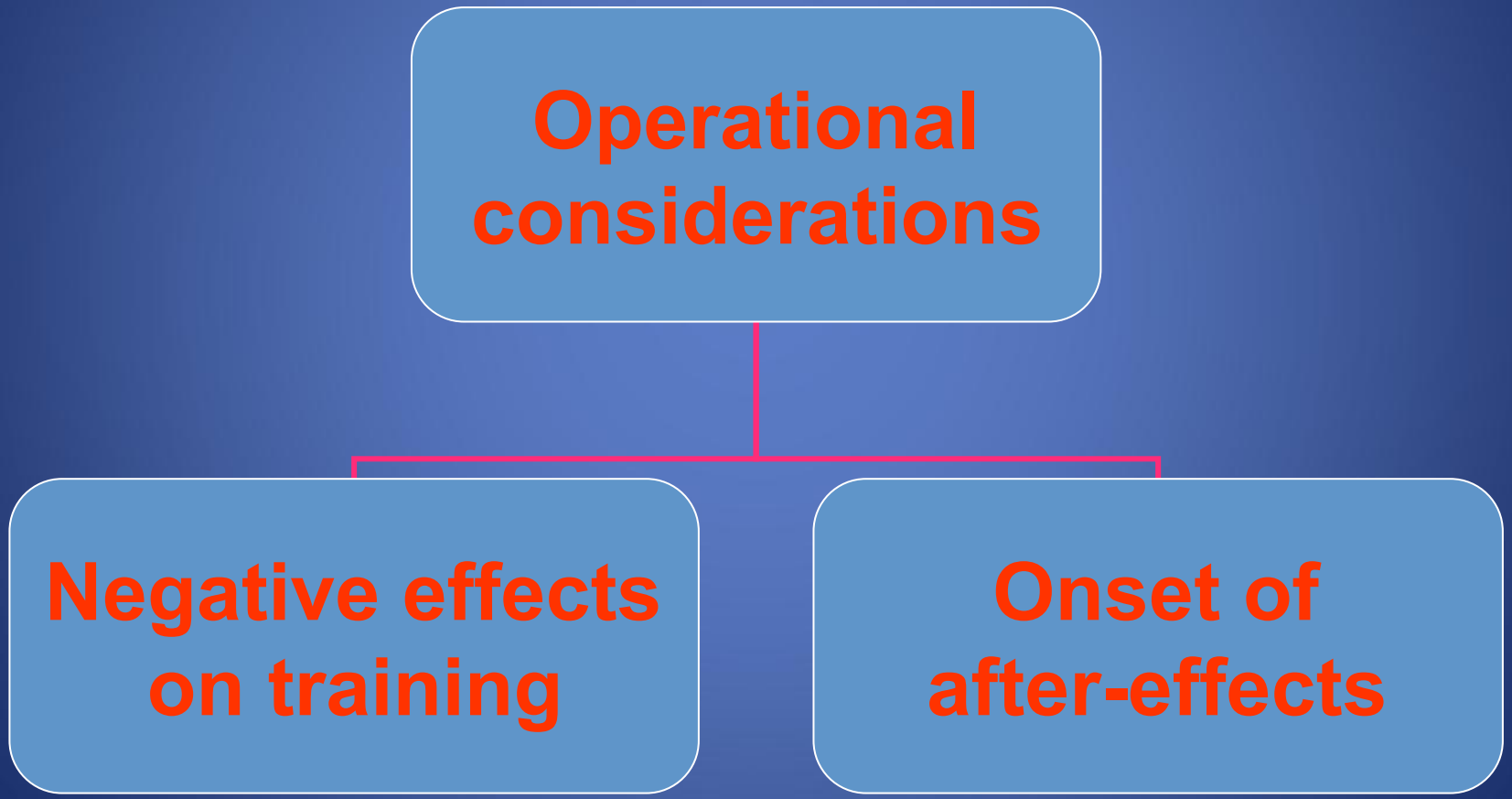


(from Lucertini et al., Phys and Behav 2007)

Anticipate susceptible individuals

- General health
- Identification:
  - New to simulator
  - High time on aircraft
  - History of MS
- Short sessions with breaks
- Decrease field of view

Instructors awareness (negative effects of SS)



Conditions contributing to SS and preventing recommendations (from Webb et al: ASEM 80: 541-5, 2009)

- session duration
- use of freeze/reset command
- unusual or unnatural meneuvers
- maneuver intensity
- height above terrain
- degree of aircraft control
- head movements
- Wide field of view visual displays
- off-axis viewing; out of design eye point or viewing region
- optical distortion caused by misaligned or poorly calibrated optics
- fatigue and sleep loss

- 2 h daily maximum
- close eyes before freeze /reset
- no flying into buildings, radio towers, or air traffic
- IP not allow SP to get too far out of control
- if discomfort arises, limit hover/ autorotation training
- if discomfort arises, remove SP from back seat
- limit head movements
- if discomfort arises,turn off side screens
- if discomfort arises, remove SP from back seat
- if visual display not “right” do not use simulator until fixed
- mantain health/rest at individual level

Implementing all of the Authors' recommendations to reduce SS will also compromise the training effectiveness.
Even more disturbing is the chance for negative transfer of training from the simulator to the actual cockpit.

(MG Lilienthal, ASEM 2009)

… at least one in five pilots has experienced a symptom after he or she has left the simulator building.
This finding has implications for safety of flight as well as for driving, and when engaging in demanding activities during off-duty hours.
Coping methods and flashbacks are two major areas in need of research for simulator sickness and flight safety.

(Baltzley et al 1989)

How to deal with SS

- Adaptation: short simulator sessions (< 2 hours) and use of breaks
- Simulator calibration & aircrew awareness
- Reduce the number of steep turns or abrupt changes in speed or pitch
- Avoid prolonged low altitude and ground manoeuvering
- Minimize freezing
- Pharmacological attempts to prevent SS can be unsuccessfull (Lucertini et al. 2007)