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Technologie, Ergonomie

Cognitive incapacitation:

theoretical and methodological consideration

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What is Cognitive Incapacitation?

In **aeronautics**, pilot **Incapacitation** is the term used to describe the **inability** of a pilot **to carry out their normal duties** as a consequence of **physiological** or **psychological factors** (SKYbrary).

It can be:

- ✓ obvious or subtle
- ✓ permanent or temporary
- ✓ complete or partial
- ✓ general incapacitation to fly due to medical reasons occurring apart from a flight
- ✓ in-flight incapacitation due to health reasons such as cardiovascular problems or loss of consciousness

All-causes incapacitation (mainly medical) could be **relatively rare** : annual rate = **0,25%** in UK commercial pilots (Evans & Radcliffe, 2012), but **could be disastrous** and with 16.145 UK professional pilots, this represents a **rate of 40/year**.

Cognitive or **mental incapacitation** is probably more frequent and was later recognized (Orlady, 1984).

Cognitive incapacitation is a state during which an individual's **cognitive abilities are temporarily impaired.**

It can be consecutive to numerous phenomena, such as :

- ✓ cognitive (over)load (Durantin et al., 2014)
- ✓ acute stress (Dismukes et al., 2015; Vine et al., 2016)
- ✓ mental fatigue (Quental et al., 2021; Reis et al., 2013)
- ✓ unexpected event (Kinney & O'Hare, 2019)
- ✓ life-threatening situations (Martin et al., 2016)

Cognitive incapacitation can happen when most of these phenomena are concomitant.

Particularly when :

High cognitive load
with time pressure



Unexpected
events



Emotional
stressors

Cognitive incapacitation is thus **different** from cognitive workload and mental fatigue, but is **related to**, as a **potential consequence** of these phenomena.

It is a **transient** phenomenon: few seconds to minutes

Cognitive incapacitation can lead to

Inefficient, inappropriate or dangerous behaviors involving:

- ✓ action or inaction, associated with
 - ✓ failures of control, comprehension, perception, or judgment
-
- ❖ Perseveration syndrome (Dehais et al., 2019)
 - ❖ Inattentional deafness and blindness (Giraudet et al., 2015)
 - ❖ Attentional tunneling (Wickens, 2005)
 - ❖ Risky decision making (Causse et al., 2013)
 - ❖ Degraded situation awareness (Jones & Endsley, 1996)
 - ❖ Startle effect (Kinney & O'Hare, 2019; Martin et al., 2016)

A contributing factor in several aircraft accidents according to BEA*

Incident to the AIRBUS - A350 - 900 registered F-HREV on 4 February 2020

“ The Airbus A350 is on final approach at Orly Airport in Paris.

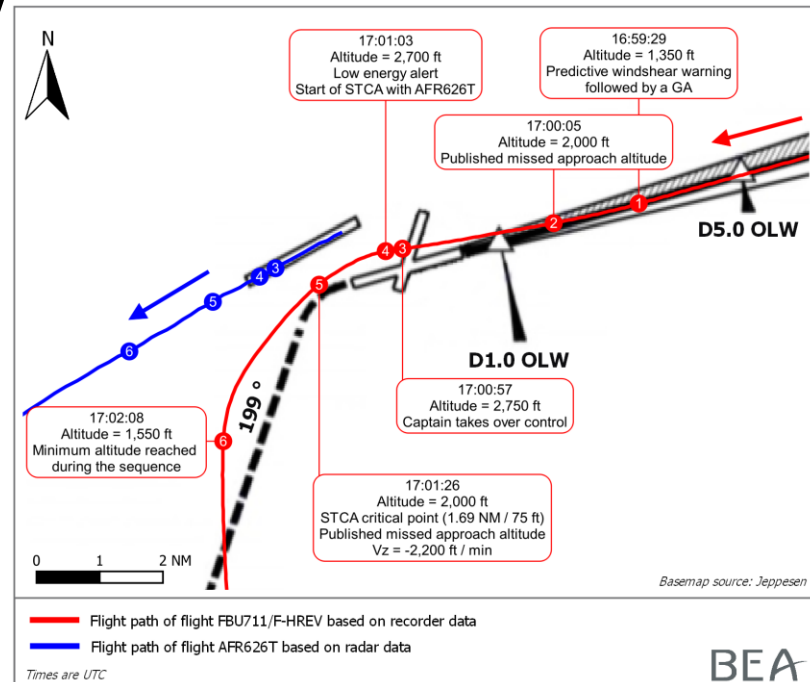
There is another aircraft taking off nearby (in blue).

At 1350 ft, there is a Predictive windshear warning, to which they respond. But problems arise.

There is a **struggle** by both crews **to comprehend** what was going on. Finally, the crew manages to engage the auto-pilot(AP) that they had disengaged before the predictive wind shear warning.

Probably the crew failed to notice this change.

In reality, for those few minutes, **no one was flying the aircraft**. Cognitive incapacitation sets in. “ – BEA –



Incident duration \approx 4 minutes.
Correct landing \approx 13 minutes later.

* Office of technical investigations of civil aviation accidents and incidents (BEA)

Particularly, the co-pilot failed to respond to imperative instructions.

*“The co-pilot indicated that there had been **moments when his mind went blank**, although he had **not been aware** of it at the time and he could only **partially remember** the sequence of the occurrence.*

*He **heard neither the calls** made by the captain and relief pilot, nor the altitude alerts in the aeroplane nor the ATC’s instructions.*

*The captain explained that all was normal but at one point he realized that the copilot **was no longer reacting, as if he was blocked.**”*

– BEA –

Cognitive incapacitation

Well documented in the professional and safety literature.

But little consensus in the scientific literature:

no clear definition, no theoretical and methodological delineation, no available literature review...

Necessity to more systematically study:

- ✓ the conditions of occurrence
- ✓ the combined behavioral, cognitive and psychophysiological correlates

Objectives:

- ✓ to early predict an episode of cognitive incapacitation,
- ✓ to better prevent their occurrence
- ✓ to better train pilots

Particularly in the context of the development of single pilot procedures.

Psychophysiological correlates of cognitive incapacitation

Psychophysiological signals already used in the field of mental workload, overload, mental fatigue, or cognitive incapacitation:


- Brain activity : EEG, fNIRS
- Muscle activity: EMG
- Ocular activity: oculometry, pupillometry
- Cardiac activity: ECG; ICG
- Electrodermal activity: GSR

See Back (2000); Borghinia et al. (2014); Dehais et al. (2020); Mandrick et al. (2016)
Proc IEA *Neurosci Biobehav Rev* *Neurosci Biobehav Rev* *Biol Psycho*

Ecological vs. Experimental studies

- **Field studies** (real flight)

-  ecological validity; induction and observation of real incapacitation episode

-  very difficult to control the environment and to collect valid unequivocal psychophysiological measures

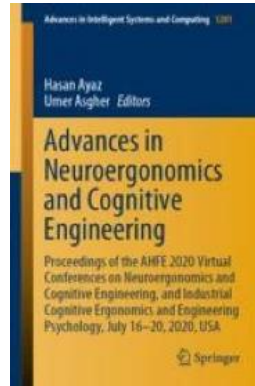
- **Laboratory settings** (experimental, simulator)

-  control; manipulation; multiplication of synchronous measurements

-  very difficult to create conditions to elicit actual cognitive incapacitation

A Neuroergonomics Approach to Measure Pilot's Cognitive Incapacitation in the Real World with EEG.

Frédéric Dehais^{1,2}, Bertille Somon¹, Tim Mullen³, Daniel E. Callan^{1,4}



2021

Five experimented pilots supervised by a safety pilot who modulated task's demands from low load to overload, in addition to navigation and maneuvering tasks.



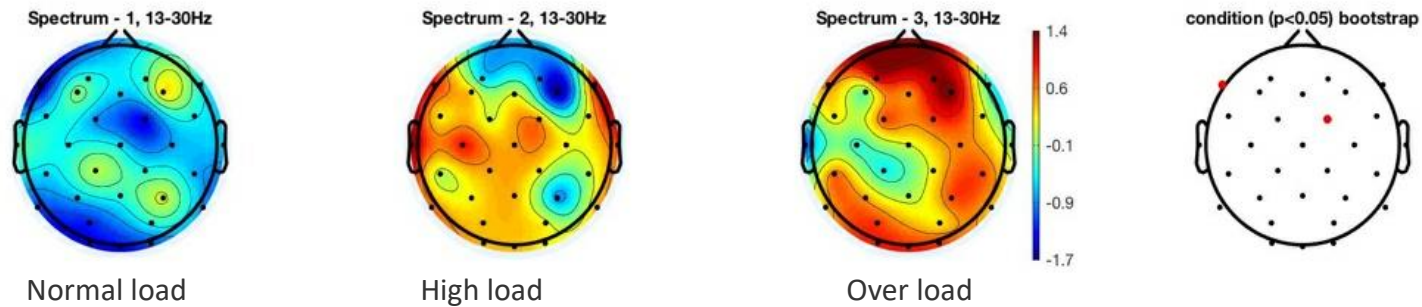
Fig. 1.: P68 ISAE-SUPAERO Experimental plane: the participant was left-seated, the flight instructor was right-seated and the back-seater was in charge of collecting the data.

EEG recording: 32 channel dry-electrodes (500 Hz).

Power spectral density analysis in the delta, theta, alpha and beta bands.

Single trial classification to detect mental state.

Overload elicited **actual cognitive incapacitation** (momentarily unable to control the airplane) **for 4 pilots** out of 5.



2-D topographical view of statistical differences in the theta band (associated to arousal and cognitive control) in predominantly prefrontal cortex electrodes.

Mean balanced classification of overload against the other loads = 89%.

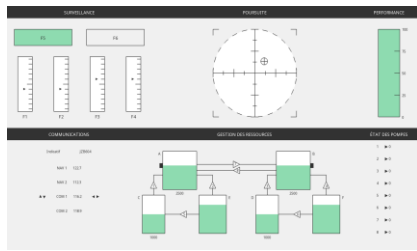
EEG activity could be due to muscle activity and other physiological artifacts.
Overload = when? How many time? Disengagement?...

A more experimental approach: the Eye-Interaction project



Multimodal study of behavioral and physiological indicators of mental load and cognitive incapacitation.

Behavior



Open MATB
(Cegarra et al., 2020)

Ocular activity



Eye-tracker
SMI RED250

Brain activity



fNIRS
NIRScout

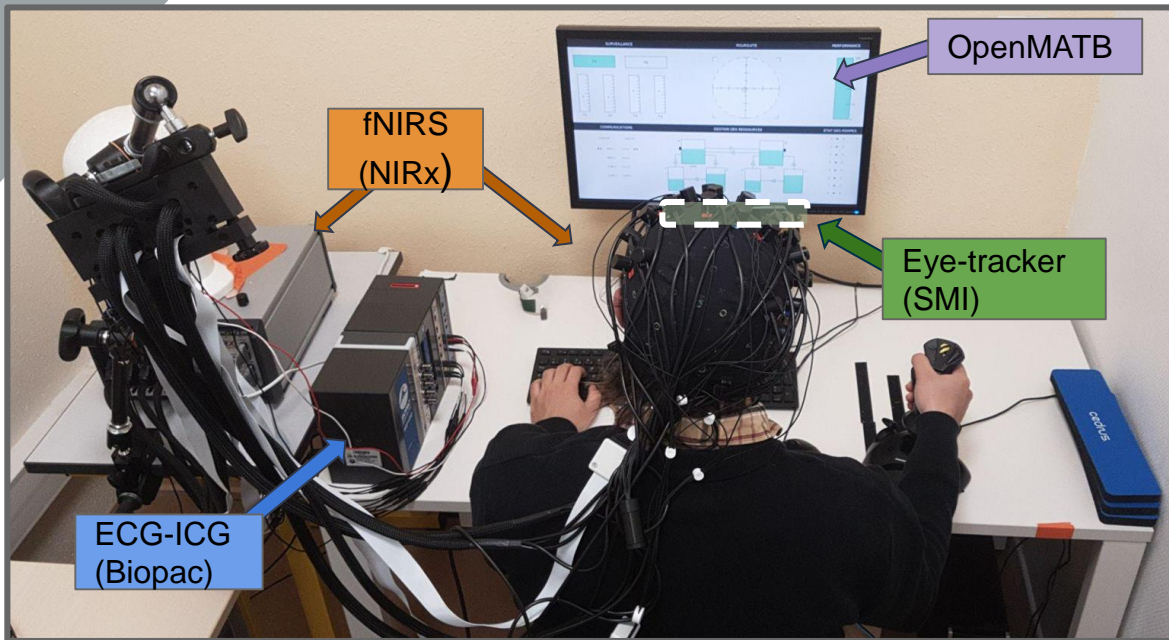
Cardiac activity



ECG – ICG
Biopac MP160

Novices vs. Experts

In collaboration with ISAE-SUPAERO (Toulouse) and ENAC (Toulouse)



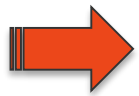
Experimental study
 Students: novices
 Open MATB: micro-world of aircraft piloting
 ↗ to overload and incapacitation?



Airbus A320 simulator
 Pilots: young experts
 Eye-Tracker (Tobii Glasses 2)
 portable ECG (Faros 360)
 EMG (Biopac MP150)
 HD camera: facial reactions
 ↗ to overload and incapacitation



The relationship between a psychological process and a physiological response is not always unequivocal or direct or universal (Cacioppo & Tassinary, 1990)



Combining multiple physiological responses may lead to:

- Better discriminate different cognitive states
- Better and early detect the onset of cognitive incapacitation



Assessment of changes in ocular, cardiac, muscular and brain activity just before, during and after an episode of cognitive incapacitation.

= signature of cognitive incapacitation ?

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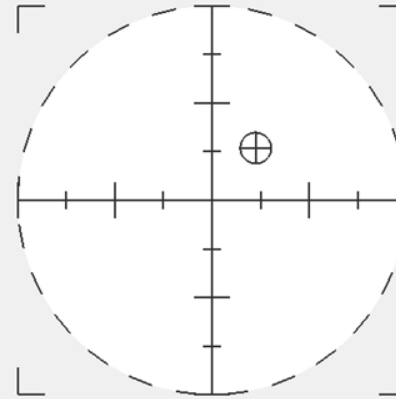
LOGICIEL OPENMATB

(Cegarra, Valéry, Avril, Calmettes & Navarro, 2020)

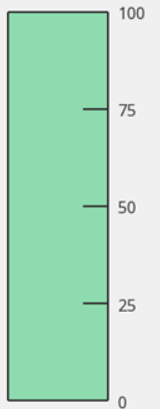
SURVEILLANCE



POURSUITE



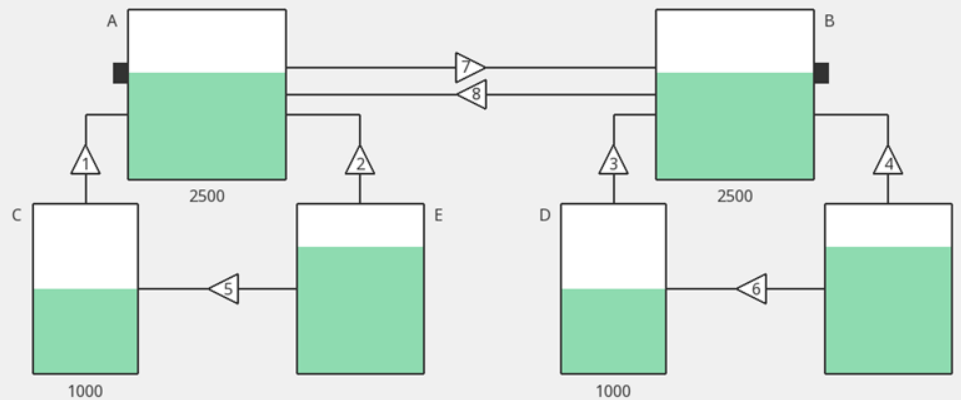
PERFORMANCE



COMMUNICATIONS

Indicatif	JZB604
NAV 1	122.7
NAV 2	112.3
▲▼ COM 1	116.2 ◀▶
COM 2	118.9

GESTION DES RESSOURCES



ÉTAT DES POMPES

- 1 ▶ 0
- 2 ▶ 0
- 3 ▶ 0
- 4 ▶ 0
- 5 ▶ 0
- 6 ▶ 0
- 7 ▶ 0
- 8 ▶ 0