Is the EEG a relevant tool of selection in military aeronautical expertise?

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I will not discuss off-label use and/or investigational use in my presentation

The opinions or assertions expressed here in are the private views of the authors and are not to be considered as official or as reflecting the views of the French Military Health Service
“... good medicine does not consist in the indiscriminate application of laboratory examinations to a patient, but rather in having so clear a comprehension of the probabilities and possibilities of a case as to know what tests may be expected to give information of value.”

Francis W. Peabody, 1922

Does EEG support valuable informations as a screening tool?
High level of medical selection

Disease’s low prevalences

Low positive predictive value of screening test

Questioning of the utility of the test
- Practices/Policies change
- Stopped use
There is no place in the aircrew for the epileptic

From physiology to aeromedical concerns

MEDICAL ASPECTS OF AIRCREW SELECTION*

By Wing Commander F. A. L. Mathewson

R.C.A.F. Medical Service, Ottawa

LOCAL CORTICAL COOLING (rabbit) DECREASE
INCREASING BODY TEMPERATURE (HUMAN) INCREASE
CORTICAL MORMIA (RABBIT) DECREASE
HYPERVENTILATION (HUMAN) DECREASE
BREATHING NITROGEN (HUMAN) INCREASE
BREATHING SULPHUR DIOXIDE (HUMAN) DECREASE
INADEQUATE OXYGEN (HUMAN) NO EFFECT

VARIATIONS IN FREQUENCY VARIATIONS IN AMPLITUDE

DECREASE INCREASE
DECREASE DECREASE
DECREASE INCREASE
DECREASE DECREASE
NO EFFECT NO EFFECT
Epilepsy

- **Prevalence**: 0.3–0.8% (by age group)  
  Hendriksen IJM, Elderson A. Aviat Space Environ Med (2001)

- **Incidence**: 0.05% per year  
  Hauser, Mayo clinic Proc (1996)  
  risk of 3.5% during life  
  Shorvon SD, Lancet (1990)
Epilepsy

GENETIC FACTORS

ACQUIRED FACTORS

FUNCTIONAL
- Metabolic
- Drugs
- Toxic

LESIONAL
- Brain injury
- Stroke
- Tumor
- Infection
- Scar tissue

« OPERATIONAL FACTORS »
- Lack of sleep
- Exhaustion (workload)
- Day-night-rhythms
- Jet Lag
- Hyperventilation
- Photic stimulation
- Hypoxia
- Stress (air strikes)
- ...

...
EEG and Epilepsy

- Epileptiform abnormalities in « healthy subjects »
  - 0.5% (from 13,000)  
  - 2.4% (from 5,000)  

- A performing test?
  - Sensitivity < 55%  
    (92% after a 4th record, Salinsky et al, 1987)
  - Specificity ≈ 97%

Correlation of Electroencephalographic Findings with Crash Rate of Military Jet Pilots

M. LENNOX-BUCHTHAL, F. BUCHTHAL AND P. ROSENFalck

Institute of Neurophysiology, University of Copenhagen, and the Aero Medical Institute, Copenhagen (Denmark)
INCIDENCE OF IN-FLIGHT EPILEPSY
- Rate of accident < acceptable minimum risk (1% rule)
- 1 in-flight seizure / 4 years (10,000 pilots)

MILITARY SERIES INCONCLUSIVE
- No/few follow up
- No recent studies
- Lack of statistical power

NOT DEMONSTRATED BENEFIT
- Rare in-flight seizures
- Registered event/countries

ANALYTIC CHALLENGES
- Pathological vs physiological paroxystic activities

UNCLEAR MEDICAL STATUS
- EEG’s loss of meaning

LOW PROGNOSTIC VALUE
- PPV: 7-8%
- Seizure’s low prevalence among applicants

Zivkin BG, Epilepsy and Behavior (2005)
Clark JB, Riley TL, Aviat Space Environ Med (2001)
Everett WD, Akhavi MS, Aviat Space Environ Med (1982)
INTERCRITICAL FINDINGS

- EEG as a «gold standard»

TRANSIENT COGNITIVE IMPAIRMENT

- «Asymptomatic» discharges
- Driver’s behavior

FLIGHT SAFETY

- Risk of accident / In-flight incapacitation
- Epilepsy: 1st cause of non-physiological LOC

MILITARY AVIATION CONCERNS

- Operational factors lowering epileptic threshold

EXTRAPOLATION MODEL

- Probability of epileptic seizure x 12 in case of «positive» EEG

INTERCRITICAL FINDINGS

- EEG as a «gold standard»

FOR

Hendriksen IJM, Elderson A. Aviat Space Environ Med (2001)
Murdoch BD. Percept Mot Skills (1993)
Rayman RB, Aerospace Med (1971)
Lennox-Buchtal M and al. Epilepsia (1959)
- MI 800 of 2008/02/20th

« doubtfal or pathological activities are leading to unfitness » :

- Definitely :
  • « Significant paroxysmal phenomenon (provoked or not by activation tests) »
  • « Focal slow activities or paroxystic discharges after brain injury »

- Temporary :
  • « Moderate and transient anomalies after a NSC agression »
  • « Fonctional anomalies provoked by an identified and resolutive context »

A 2nd expert opinion possible at request of the applicant (after 2nd rest EEG, sleep deprivation EEG, cerebral MRI...)
Retrospective studies

2 prevalence studies

- N°2: AeMC Sainte-Anne Military Hospital (Toulon): 1 year (2016)

1 impact study

1) Materials and methods

- **Type**:
  - 2 retrospective, descriptive, transverse and monocentric studies
  - Based on EEG analysis performed

- **Population**:
  - Military applicants for aircrew and air traffic air controllers

- **Purpose**:
  - To observe and classify EEG anomalies to deduct a prevalence
4,061 patients included
- 3,911 (96.3%) : strictly normal
- 150 (3.7%) : abnormal or doubtful

3,413 ♂ / 648 ♀ (Sex Ratio : 5)
Average age : 22 years
Median age : 20 years

3,061 patients included
- 288 (92%) : strictly normal
- 25 (8%) : abnormal or doubtful

265 ♂ / 48 ♀ (Sex Ratio : 5.5)
Average age : 22 years
Median age : 21 years

Clamart
Epileptiform pattern
Overload of slow activities

Toulon

% of EEG records
0.00 2.00 4.00 6.00 8.00 10.00
2) Results

- total anomalies revealed by activation tests
  - Clamart: 35%  
  - Toulon: 20%

- rest anomalies majored by hyperpnea
  - Clamart: 50%  
  - Toulon: 67%

Global unfitness rate:
  - Clamart: 2.4%  
  - Toulon: 6.7%
Typical paroxysmal phenomena

Atypical paroxysmal phenomena

Overload of slow activities (delta/thêta)

Diffuse slow waves bursts

Other patterns

Rate of unfitness according to described anomalies (Clamart)

« Epileptiform patterns » = 50.5% of the causes of unfitness
Rate of unfitness according to described anomalies (Toulon)

- **Focalized slow waves bursts**: 33% unfitness, 67% fitness
- **Diffuse slow waves bursts**: 87.5% unfitness, 12.5% fitness
- **Paroxysmal phenomena**: 100% unfitness, 0% fitness

« Epileptiform patterns » = 28.6% of the causes of unfitness
<table>
<thead>
<tr>
<th>Author (Ref.)</th>
<th>Date</th>
<th>Subjects</th>
<th>Abnormal EEG (%)</th>
<th>Epileptiform EEG (%)</th>
<th>Follow-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lachaud et al.</td>
<td>1971</td>
<td>French pilot candidates, 18-22 years</td>
<td>152/2700 (5.63%)</td>
<td>73/2700 (2.7%)</td>
<td>-</td>
</tr>
<tr>
<td>LeTourneau &amp; Metten</td>
<td>1973</td>
<td>Naval aviation students, 19-29 years</td>
<td>38/28558 (0.13%)</td>
<td>21/28558 (0.07%)</td>
<td>1 of 31 with an abnormal EEG located a seizure in 11 years follow-up</td>
</tr>
<tr>
<td>Osterholz</td>
<td>1976</td>
<td>German AF candidates, 15-57 years</td>
<td>61/973 (6.3%)</td>
<td>13/973 (1.34%)</td>
<td>-</td>
</tr>
<tr>
<td>Maudlsby et al.</td>
<td>1976</td>
<td>French AF pilots and other crew members</td>
<td>2050/10000 (20.5%)</td>
<td>250/10000 (2.5%)</td>
<td>No seizure after 4-10 years</td>
</tr>
<tr>
<td>Robin et al.</td>
<td>1978</td>
<td>USAF male aviators, 18-55 years</td>
<td>166/7760 (2.14%)</td>
<td>76/7760 (0.98%)</td>
<td>1 of 20 followed up had a seizure during EEG recording</td>
</tr>
<tr>
<td>Everett &amp; Alkawi.</td>
<td>1982</td>
<td>USAF Academy cadets, 4th year</td>
<td>85/2947 (2.9%)</td>
<td>14/2947 (0.48%)</td>
<td>No seizures after 10-15 years</td>
</tr>
<tr>
<td>Trojaborg</td>
<td>1992</td>
<td>RDAF male applicants, 17-28 years</td>
<td>14/2593 (2.4%)</td>
<td>Mainly paroxysmal (≤ 2.4%)</td>
<td>(4 applicants developed a seizure during EEG recording)</td>
</tr>
<tr>
<td>Gregory et al.</td>
<td>1993</td>
<td>RAF candidates, 17-25 years</td>
<td>-</td>
<td>69/13658 (0.5%)</td>
<td>1 of 38 followed up had a seizure during 5-29 years follow-up</td>
</tr>
<tr>
<td>Ribeiro</td>
<td>1994</td>
<td>AF pilot applicants and other crew applicants</td>
<td>92/2015 (4.57%)</td>
<td>38/2015 (1.89%)</td>
<td>(1 with a normal initial EEG had a seizure during 13 years follow-up)</td>
</tr>
<tr>
<td>Ferain</td>
<td>2017</td>
<td>French aircrew and air-traffic control applicants</td>
<td>120/4016 (3.7%)</td>
<td>51/4016 (1.3%)</td>
<td>1 of 44 followed up with a seizure during prophylaxis by methoquine</td>
</tr>
<tr>
<td>Huiban</td>
<td>2017</td>
<td>French aircrew and air-traffic control applicants</td>
<td>25/313 (8%)</td>
<td>6/313 (1.9%)</td>
<td>-</td>
</tr>
</tbody>
</table>
Impact study (N°3)

- **Type :**
  - An analytical and *descriptive* study of a *longitudinal* and *multicentric cohort*.

- Population included between **2007/01** and **2016/02**.

- Use of a *questionnaire*

- **Purpose :**
  - To draw a *pronostic value of abnormal EEGs previously observed*
Impact study (N°3)

- Population:

143 applicants

Unfit (no request)  N = 59

Unfit (after request)  N = 84

- Participation: 30% (44 returns of filled questionnaires)
- Average age: 26.7 years
- Mean length of follow-up: 4.8 years

<table>
<thead>
<tr>
<th>Age groups (years)</th>
<th>Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td>16-19</td>
<td>1</td>
</tr>
<tr>
<td>20-24</td>
<td>13</td>
</tr>
<tr>
<td>25-29</td>
<td>19</td>
</tr>
<tr>
<td>30-34</td>
<td>8</td>
</tr>
<tr>
<td>35-39</td>
<td>2</td>
</tr>
</tbody>
</table>
2) Results

- Convulsions (x 2)
- Loss of contact (x 1)
- "COMPATIBLE » CLINICAL SPECTRUM"
- Generalized seizure (x 1)
- Sensory hallucinations (x 1)
- Abnormal motion (x 1)
- Loss of consciousness (x 1)

×3 discomfort
+/- « loss of consciousness »
1 of 44 followed up with a seizure during prophylaxy by mefloquin

TABLE 1
Follow-up studies.

<table>
<thead>
<tr>
<th>Author</th>
<th>Year</th>
<th>Population</th>
<th>No. followed</th>
<th>No. developing epilepsy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zivin</td>
<td>1968</td>
<td>Medical</td>
<td>47</td>
<td>1</td>
</tr>
<tr>
<td>Le Tourneau</td>
<td>1973</td>
<td>U.S. Navy</td>
<td>31</td>
<td>1</td>
</tr>
<tr>
<td>King</td>
<td>1974</td>
<td>USAF</td>
<td>30</td>
<td>1</td>
</tr>
<tr>
<td>Everett</td>
<td>1982</td>
<td>USAF</td>
<td>14</td>
<td>0</td>
</tr>
<tr>
<td>Gregory</td>
<td>1992</td>
<td>RAF</td>
<td>38</td>
<td>1</td>
</tr>
</tbody>
</table>

Ferain 2017 French Army 44 1

204 / 5 = 2.5%

A relevant decision
A relevant decision

Risk of future epilepsy?
- “Ep. Discharges” ≠ pathognomonic
  → Higher incidence? (combined data)
  → Predisposition?
  → large control group required (not available or impossible)

T.C.I. due to “Ep. Discharges”?
- Effects on drivers behavior → flight safety?

Cost-benefits ratio?
- Dual purpose
  - Cost of “one avoided incident”

Ways for a decision
Epileptiform pattern → ≠ Epilepsy
  → “Functional traits” susceptible to be translated by neurological signs / seizure in conditions of reducing threshold (operational factors)
EEG: a tool of the past?
Perspectives

• **Long term monitoring EEG**: paroxysmal activity studied over extended periods (data compression algorithms / automatic detection of grapho-elements)

• **Video-EEG**: behavioral manifestations consistent with T.C.I.

• Functionnal brain mapping: **HR-EEG** and **MEG** (spatial resolution)

• A study on the **significance** of epileptiform paroxysms (simulation training)
  
  → creation of large and searchable **databases**

  → to establish and validate the **risks for developing epilepsy**

*Velis ND, Epilepsy & Behavior (2005)*
Thank you for attention