Rafale F3R Fighter Jet - New Croatian Aircraft

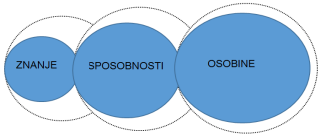
1

1

Inicijalne karakteristike pilotskih kandidata

POTREBAN JE ODREĐENI NIVO ZNANJA, SPOSOBNOSTI I OSOBINA

Kod kandidata je najmanji moguć utjecaj na osobine, te je bitna visoka razina poželjnih osobina *na* samom početku procesa selekcije i obuke.



Što može znanost?

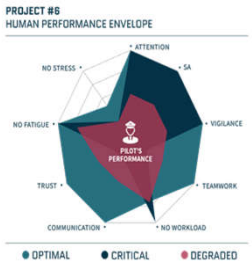
Znanost može proizvesti nove metode i alate :

- kojima se mogu pospješiti procesi selekcije i obuke
- za veću održivost borbenih sposobnosti i otpornost pojedinaca izloženih borbenim traumama i stresu
- "*Ne preživljavaju najjači, niti najinteligentniji pojedinci u vrsti već oni koji su najsposobniji prilagoditi se promjenama.*" - Charles Darwin

2

Relevant Former EU Future Sky Safety Project Illustration "Project #6: Human Performance Envelope"

Human Performance Envelope project proposes a variety of physiological, speech/voice processing, oculometric and neurometric approaches in order to evaluate the factors/axes of the Human Performance Envelope



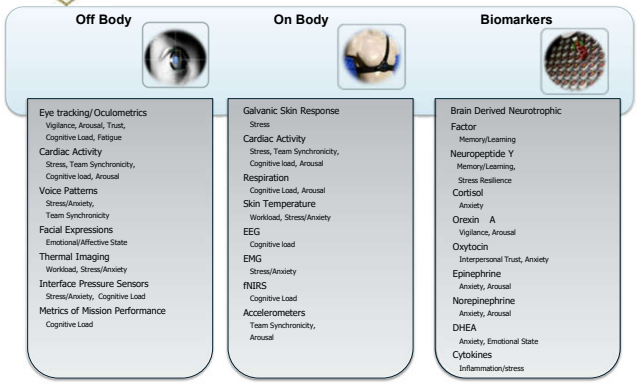
	WL	Stress	Fatigue	SA	Attention	Vigilance	Teamwork	Comm.	Trust
ECG	X	X	X	X	X	X			
EEG	X		X	X	X	X			
EMG	X	X	X						
EOG	X	X	X	X	X	X			
fNIR	X			X	X				
GSR/EDA	X	X	X						
Respiratory activity	X	X	X						
Eye-tracking	X	X	X	X	X				X
Subjective measures	X	X	X	X					
Primary / secondary task	X		X	X	X				
Expert observation	X			X	X		X	X	X
Communication analysis		X		X			X	X	
Seat sensors	X	X							
Voice analysis	X	X							
Pressure / grip sensors		X							
Polygraph sensor		X							
Electrochemical sensors		X							

Silvagni, S., Napoletano, L., Graziani, I., Le Blaye, P., & Rognin, L. (2017). Concept for human performance envelope. https://www.futuresky-safety.eu/wp-content/uploads/2015/12/FSS_P6_DBL_D6.1-Concept-for-Human-Performance-Envelope_v2.0.pdf

3

3

Relevant Former U.S. Project Illustration: Applied Neuroscience in Defense Setting Sense Technologies



4

EUROPEAN DEFENCE FUND

EUROPEAN UNION

EPIIC

Enhanced Pilot Interfaces & Interactions for fighter Cockpit

SELECTED PROJECTS EUROPEAN DEFENCE FUND (EDF) 2021

CALL TITLE:	Avionics and advanced air combat
TOPIC TITLE:	Enhanced pilot environment for air combat
DURATION OF THE PROJECT:	36 months
TYPE(S) OF ACTIVITIES:	Studies
ESTIMATED TOTAL COST:	€ 77,769,904.62
MAXIMUM EU CONTRIBUTION :	€ 74,999,974.60

5

The European project Enhanced Pilot Interfaces & Interactions for Fighter Cockpit (EPIIC) aims to identify, develop and evaluate disruptive cockpit technologies that will revolutionize the collaborative air combat of the future. Funded with €75 million from the European Defence Fund, this project, coordinated by Thales, brings together a consortium of 27 manufacturers and research organizations from 12 European countries. [1]

THALES, indra, DASSAULT AVIATION, AIRBUS, LEONARDO, SAAB, AALBORG UNIVERSITY, DIEHL Aerospace, DLR, ESG, gmv, HAT, INCAS, UNIVERSITY OF PATRAS, nlr, Collins Aerospace, tecnobit, TERMA, FER, INSTA, alma, eti, NEXT2U, FOI

Focus of FER Laboratory for Interactive Simulation Systems

Objectives

The EPIIC project aims to enhance air power capabilities and ensure air dominance for the European Armed Forces. To achieve this, the project has set clear and ambitious objectives that seek to address the techno-logical challenges of future air warfare and collaborative combat.

- Cockpit innovations consistency
- Adaptive HMI (Human-Machine Inter-face)
- Innovative Virtual Assistant
- Innovative Large Area Displays
- Eyes-out technologies
- Crew Monitoring Sensors and Physio-logical States
- Crew states identification algorithms
- Innovative Interaction Modalities

https://www.thalesgroup.com/en/worldwide/defence/press_release/thales-takes-lead-european-epiic-research-project-design
https://edf-epiic-project.eu/sites/default/files/2023-06/EPIIC%20Leaflet%20V2-%20Final%20Version.pdf

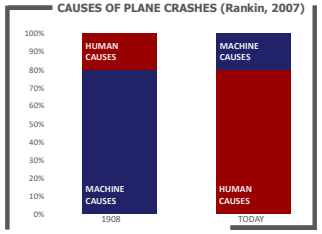
6

Human Factors in Military Aviation

Human factors refer to environmental, organisational and job factors, and human and individual characteristics, which influence behaviour at work in a way which can affect health and safety (Health and Safety Executive).

- Human factors research goals (Wickens et al., 2004):
  - Reducing error,
  - Increasing productivity,
  - Enhancing safety,
  - Enhancing comfort.
- Croatian Air Force Accidents:
  - Mi-8 helicopter crash (Jul. 2007)
  - Clash of two MiG-21 fighters (Sep. 2010)
  - MiG-21 fighter crash (Aug. 2014)
  - Kiowa Warrior helicopter crash (Jan. 2020)
  - School plane crash (May. 2020)

→ Objectivized assessment of stress and cognitive resilience in the early phases of pilot selection



→ 60-80% plane crashes are caused by human factors

Rankin, W. (2007). MEdA investigation process. *Boeing Commercial Aero.*
Wickens, C. D., Gordon, S. E., Liu, Y., & Lee, J. (2004). *An introduction to human factors engineering* (Vol. 2). Upper Saddle River, NJ: Pearson Prentice Hall.
Health and Safety Executive: Introduction to human factors, available at: https://www.hse.gov.uk/humanfactors/introduction.htm.

7

Human Factors in Military Aviation

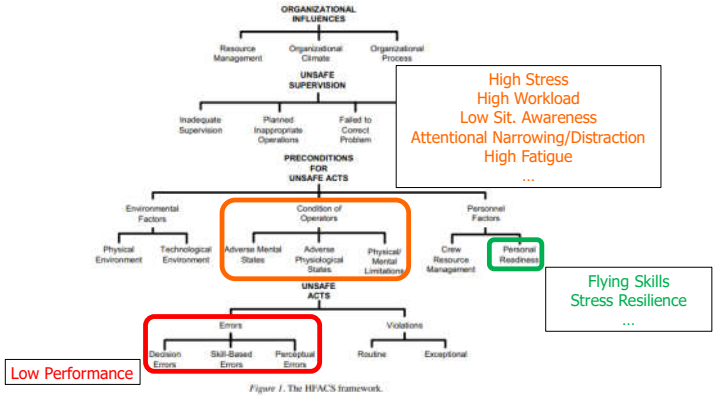


Figure 1. The HFACS framework.

High Stress
High Workload
Low Sit. Awareness
Attentional Narrowing/Distraction
High Fatigue
...

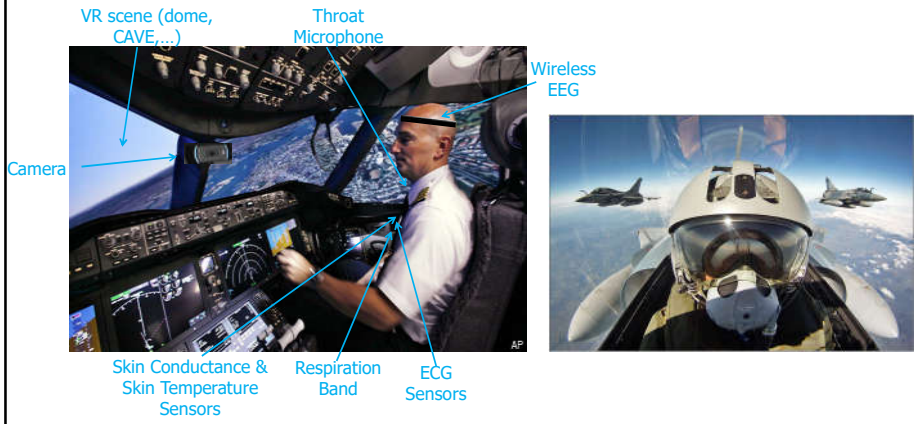
Flying Skills
Stress Resilience
...

Low Performance

Shappell, S., Detwiler, C., Holcomb, K., Hackworth, C., Boquet, A., & Wiegmann, D. A. (2007). Human Error and Commercial Aviation Accidents: An Analysis Using the Human Factors Analysis and Classification System. *Human Factors*, *49*(2), 227-242. Link. Cited by 515.

8

Multimodal Estimation of Pilot's Mental States



9

Stress Resilience: Important Characteristic for Task Performance under Stress

TO THIS day a variety of definitions, concepts, and theories of psychological resilience have been proposed, but most are based on two main concepts: adversity and positive adaptation, with resilience being defined as the process of positive adjustment to adverse events [1]. In the context of exposure to potentially traumatic events, resilience is seen as the absence of trauma-related psychiatric disorder sypmtoms [2]. However, in a task-related context resilience is defined as the ability of maintaining normal psychological and physical functioning, when exposed to extraordinary levels of stress and trauma [3].

Ćosić, K., Šarlija, M., Ivkovic, V., Zhang, Q., Strangman, G., & Popović, S. (2019b). Stress resilience assessment based on physiological features in selection of air traffic controllers. IEEE Access, 7, 41989-42005. Link.

[1] S. M. Southwick, G. A. Bonanno, A. S. Masten, C. Panter-Brick, and R. Yehuda, "Resilience definitions, theory, and challenges: Interdisciplinary perspectives," *Eur. J. Psychotraumatol.*, vol. 5, no. 1, 2014, Art. no. 25338. Cited by 2202

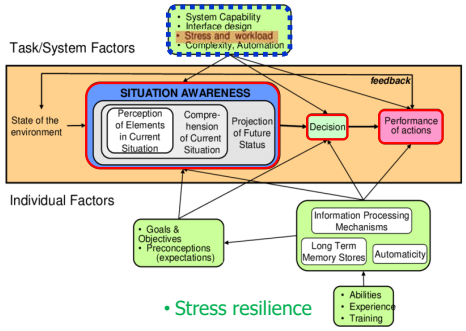
[2] F. R. Walker, K. Pfingst, L. Carnevali, A. Sgoifo, and E. Nalivaiko, "In the search for integrative biomarker of resilience to psychological stress," *Neurosci. Biobehav. Rev.*, vol. 74, pp. 310–320, 2017. Cited by 150

[3] S. J. Russo, J. W. Murrough, M.-H. Han, D. S. Charney, and E. J. Nestler, "Neurobiology of resilience," *Nature Neurosci.*, vol. 15, no. 11, 2012, Art. no.1475. Cited by 1122

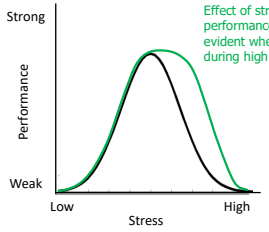
10

Stress Resilience Is NOT ... but Has Impact on All That

- Ability to do the task
- Ability to make right decisions
- Ability to understand complex operational situation



Endsley, M. R. (2017). Toward a theory of situation awareness in dynamic systems. In Situational awareness (pp. 9-42). Routledge. Cited by 10675.



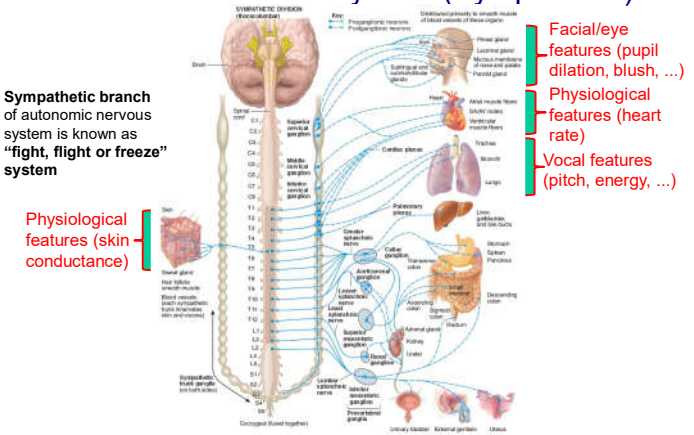
Effect of stress resilience on task performance should be most evident when performing tasks during high levels of stress

Russo, S. J., Murrough, J. W., Han, M. H., Charney, D. S., & Nestler, E. J. (2012). Neurobiology of resilience. *Nature neuroscience*, *15*(11), 1475-1484. Link. Cited by 1123.

11

Stress Effects on The Body via Autonomic Nervous System (Sympathetic)

Sympathetic branch of autonomic nervous system is known as **"fight, flight or freeze" system**

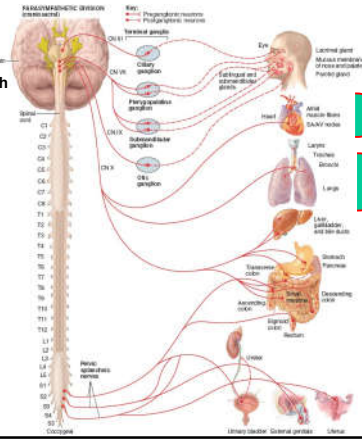


http://higheredbcs.wiley.com/legacy/college/tortora/0470565101/hearthis_ill/pap13e_ch15_illustr_audio_mp3_am/simulations/hear/sympathetic.html

12

Stress Effects on The Body via Autonomic Nervous System (Parasympathetic)

Parasympathetic branch of autonomic nervous system is known as **"rest and digest" system**



Facial/eye features

Physiological features (heart rate)

Vocal features

Nigdje nema inervacije kože! Na kožu utječe samo simpatička grana autonomnog živčanog sustava

13

13

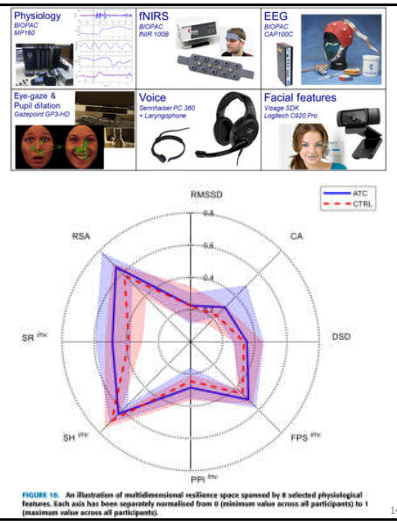
Stress Resilience Assessments

In terms of cost-effectiveness and reliability we can divide the resilience assessment tools into 3 groups:

1) Psychometric tools for stress resilience assessment which are time- and cost- effective, but are susceptible to self-report bias.
2) High-cost metrics that might allow a deep and accurate insight into the biological factors contributing to one's resilience, whose assessment is intrusive and highly demanding in terms of organisation and time (MRI, fMRI, fear conditioning/extinction, genes, gene expressions, etc.).
3) Various features based on the objectively measurable responses of the peripheral physiology that are relatively weakly associated to deeper traits/states like stress resilience.

Most expensive and time consuming

Ćosić, K., Šarlija, M., Ivković, V., Zhang, Q., Strangman, G., & Popović, S. (2019b). Stress resilience assessment based on physiological features in selection of air traffic controllers. IEEE Access, 7, 41989-42005. Link.

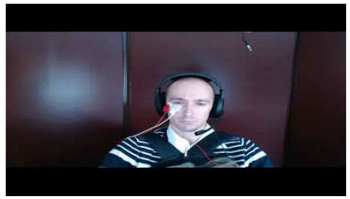


14

14

Akustička *startle* reakcija i njen značaj za predikciju rezilijentnosti

- *Startle* reakcija je obrambeni refleks za zaštitu od iznenadnih podražaja
- Važna je npr. jer je visoka anksioznost povezana s jačom *startle* reakcijom, strah/stres pojačavaju *startle* reakciju, osobe s PTSP-om imaju pojačanu *startle* reakciju, odnosno pojačani intenzitet *startle* reakcija povezuje se s vulnerabilnošću tj. nerezilijentnošću na visoke razine stresa
- Laboratorijska akustička *startle* stimulacija pouzdano proizvodi *startle* reakciju, kroz refleksni neuronski put koji sadrži 3 neurona
  - Bijeli šum, 40 ms, 108 dB

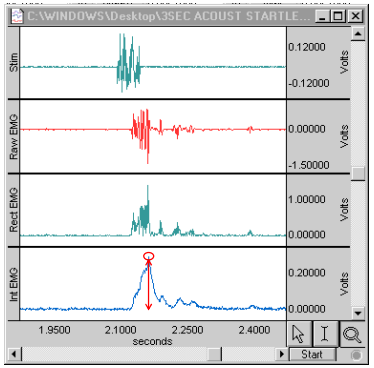


Eleonora Poli and Alessandro Angrilli. Greater general startle reflex is associated with greater anxiety levels... Front Behav Neurosci. 2015; 9: 10. Published online 2015 Feb 6.

15

15

Akustička *startle* reakcija standardno se mjeri pomoću EMG fiziološkog signala očnog mišića



Akustička *startle* stimulacija

Sirovi EMG očnog mišića

Ispravljeni EMG (apsolutna vrijednost EMG-a)

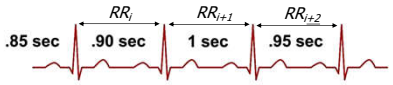
Integrirani ispravljeni EMG, dobiven pomičnim prozorom određene širine
+
značajka koja predstavlja jačinu *startle* reakcije

16

16

Značaj rada srca i disanja u predikciji rezilijentnosti na stres

- **<u>Srce ne kuca jednoliko!</u>**
- Varijabilnost srčanog ritma
  - Varijacije u trajanjima intervala između otkucaja srca
  - engl. Heart Rate Variability (**HRV**)

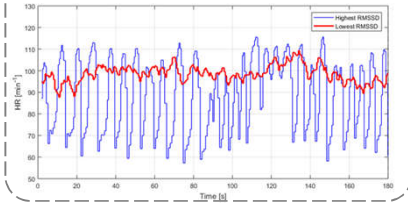


- Otkriva nam puno više od same informacije o srčanom ritmu (HR) ili njegove prosječne vrijednosti
- Osnovni primjeri značajki HRV-a u vremenskoj domeni

SDNN	Standard deviation of all RR intervals	$SDNN = \sqrt{\frac{\sum_{i=1}^{N}(RR_i - \overline{RR})^2}{N}}$
RMSSD	Square root of the mean of the sum of the squares of differences between RR interval	$RMSSD = \sqrt{\frac{\sum_{i=1}^{N-1}(RR_{i+1} - RR_i)^2}{N-1}}$

SIMPATIKUS
- Stimulira rad srca
- Povisuje srčani ritam i volumen otkucaja
- Odziv nakon nekoliko sekundi

PARASIMPATIKUS
- Inhibira rad srca
- Snižava srčani ritam i povećava HRV
- Odziv praktički odmah

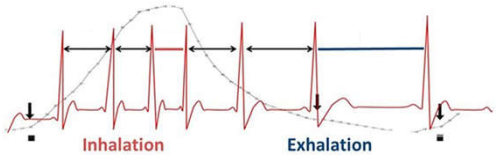


17

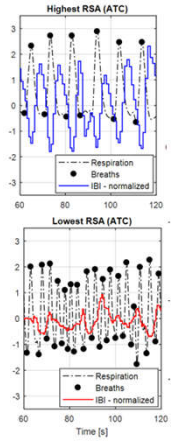
17

Respiratorna sinusna aritmija (RSA)

- RSA is defined as heart rate variability (HRV) synchronised with respiration, marked by heart rate increase during inspiration and heart rate decrease during expiration



- Physiologic role: enhancing the efficiency of respiratory gas exchange
- Psychophysiological importance: index (biomarker) of emotion regulation capacity
  - low RSA was observed in various psychopathological states related to emotion dysregulation (e.g. anxiety disorders, bipolar disorder, depression)
  - pronounced RSA was found to be a marker of protective traits like stress resilience



18

18

Kognitivno opterećenje

- Kognitivno opterećenje je opterećenje kognitivnog sustava tijekom izvedbe određenog zadatka [1]
- Različiti faktori utječu na kognitivno opterećenje:
  - Težina zadataka
  - Razina stručnosti osobe koja izvodi zadatak
  - Dob
- Kognitivno opterećenje može se mjeriti:
  - Performancama na zadacima (npr. točnost i vrijeme odgovora na zadatak)
  - Subjektivnim mjerama iskaza (npr. NASA TLX, Instantaneous Self Assessment – ISA) prikupljenim tijekom i nakon izvođenja zadataka [2,3]
  - Neurofiziološkim mjerama prikupljenima tijekom izvođenja zadataka [4]
    - Kako anotirati zadatke?
  - Kombinacijom navedenih mjera [5]

Planning complex cognitive behavior, decision making, working memory ...:
PREFRONTAL CORTEX

[1] Paas, F. G., & Van Merriënboer, J. J. (1994). Instructional control of cognitive load in the training of complex cognitive tasks. Educational psychology review, 6(4), 351-371.
[2] Hart, S. G., & Staveland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In Advances in psychology (Vol. 52, pp. 139-183). North-Holland.
[3] Jordan, C. S., & Brennen, S. D. (1992). Instantaneous self-assessment of workload technique (ISA). Defence Research Agency, Portsmouth.
[4] Ćosić, K., Popović, S., Šarlija, M., Mijić, I., Kokot, M., Kesedžić, I., ... & Zhang, Q. (2019). New Tools and Methods in Selection of Air Traffic Controllers Based on Multimodal Psychophysiological Measurements. IEEE Access, 7, 174873-174888.
[5] Arico, P., Reynal, M., Di Flumeri, G., Borghini, G., Sciaraffa, N., Imbert, J. P., ... & Betti, V. (2019). How neurophysiological measures can be used to enhance the evaluation of remote tower solutions. Frontiers in Human Neuroscience, 13.

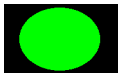
19

19

Ilustracije generičkih računalnih testova za kognitivne funkcije

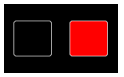
- *Simple reaction time test*
  - psihomotorička brzina
  - što prije treba pritisnuti tipku na tipkovnici svaki puta kada se pojavi krug na ekranu

Simple Reaction Time test



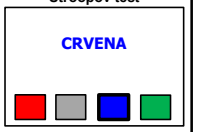
- *Go/no-go test*
  - psihomotorička brzina + inhibicija reakcije
  - što prije treba pritisnuti tipku na tipkovnici svaki puta kada se pojavi zeleni kvadrat, a ne smije se pritisnuti tipka na pojavu crvenog kvadrata

Go/No-Go test



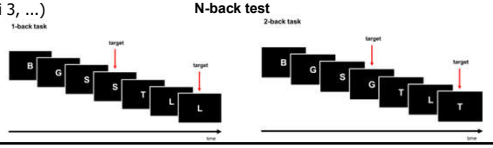
- *Stroopov test*
  - inhibicija kognitivne interferencije
  - svaki puta kada se na ekranu pojavi napisana riječ, odgovoriti kojom bojom je riječ napisana

Stroopov test



- *N-back* test (N = 1 ili 2 ili 3, ...)
  - radna memorija

N-back test



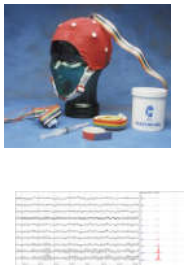
20

20

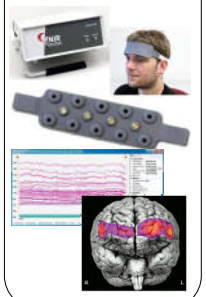
Tehnike oslikavanja mozga

- Magnetska rezonancija (engl. *magnetic resonance imaging* – MRI)
  - strukturni MRI
  - funkcionalni MRI (fMRI)
- Elektroencefalografija (engl. *electroencephalography*, EEG)
- Funkcionalna blisko-infracrvena spektroskopija (engl. *functional near-infrared spectroscopy*, fNIRS)

EEG



fNIRS

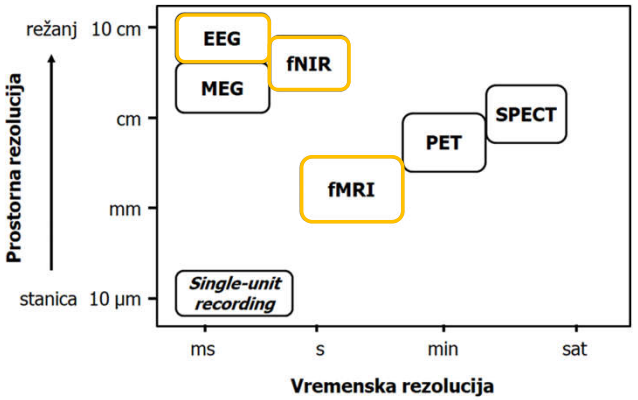


MRI/fMRI

21

21

Prostorno-vremenska rezolucija tehnika oslikavanja mozga



22

22

fMRI

- Neinvazivna tehnika koja prati promjene povezane s protokom krvi u mozgu
  - bazirano na pretpostavci da se prokrvljenost povećava u trenucima povećane aktivacije pojedinog dijela mozga
- Prednosti:
  - neinvazivan
  - dobra prostorna rezolucija
  - moguća su snimanja cijelog mozga
- Nedostatci:
  - niska vremenska rezolucija
  - nije prenosiv
  - nisu moguća snimanja na terenu
  - visoka cijena
  - uski prostor
  - visoka buka

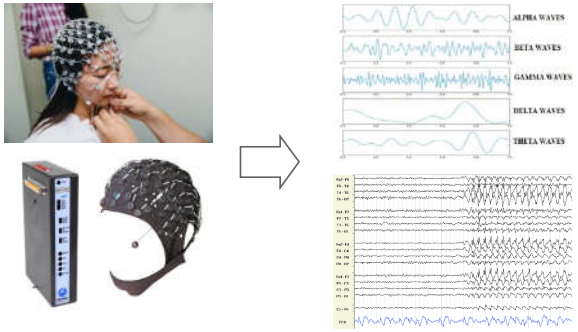
Letter-word generation (LWG) task example

23

23

Elektroencefalografija

- Snimanje električne aktivnosti mozga
- Složena tehnika mjerenja moždane aktivnosti



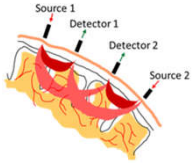
24

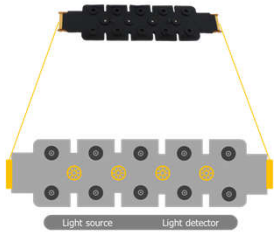
24

fNIRS

- Neinvazivna tehnika oslikavanja mozga
  - omogućuje praćenje prokrvljenosti prefrontalnog korteksa
  - mjerenje radne memorije, pažnje, rješavanja problema, odlučivanja
- Odziv mozga na pobudu
  - 2-6 sekundi
- Prednosti:
  - prenosiv, moguća snimanja na terenu
  - neinvazivan
  - pristupačna cijena
  - jednostavan za korištenje
- Nedostatci:
  - ograničenja s kosom ispitanika, moguća su snimanja samo na čeonom dijelu
  - ograničenja s regijama mozga koje se mogu promatrati
  - nepostojanje informacija o strukturama promatranih regija

fNIRS control box and sensor in Laboratory for Interactive Simulation Systems

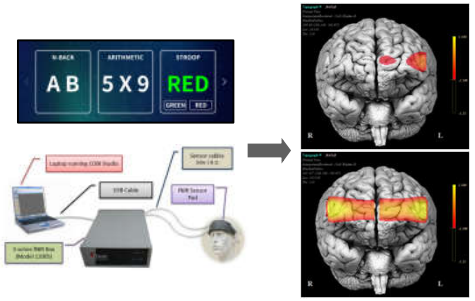


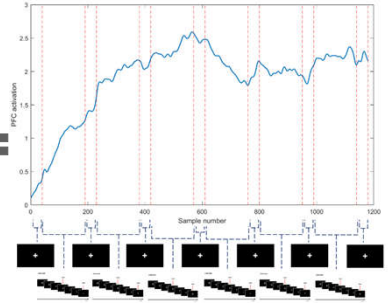


25

25

fNIRS



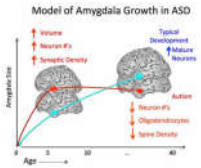


26

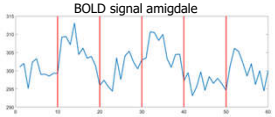
26

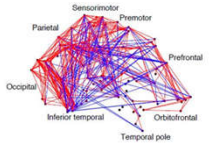
Informacije koje sadrže podaci snimljeni različitim tehnikama oslikavanja mozga

- MRI:
  - veličina i oblik struktura u mozgu

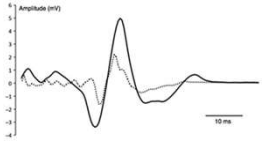


- fMRI:
  - blood-oxygen-level dependent (BOLD) signal
  - povezanost među regijama mozga

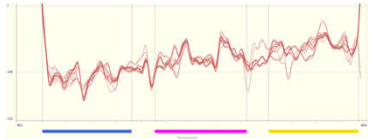




- EEG:
  - evocirani potencijali
  - spektralne snage u pojedinim frekvencijskim pojasima



- fNIRS:
  - zasićenost krvi kisikom



27

27