Non-EEG based seizure detection: necessity, availability, possibilities, requirements and challenges

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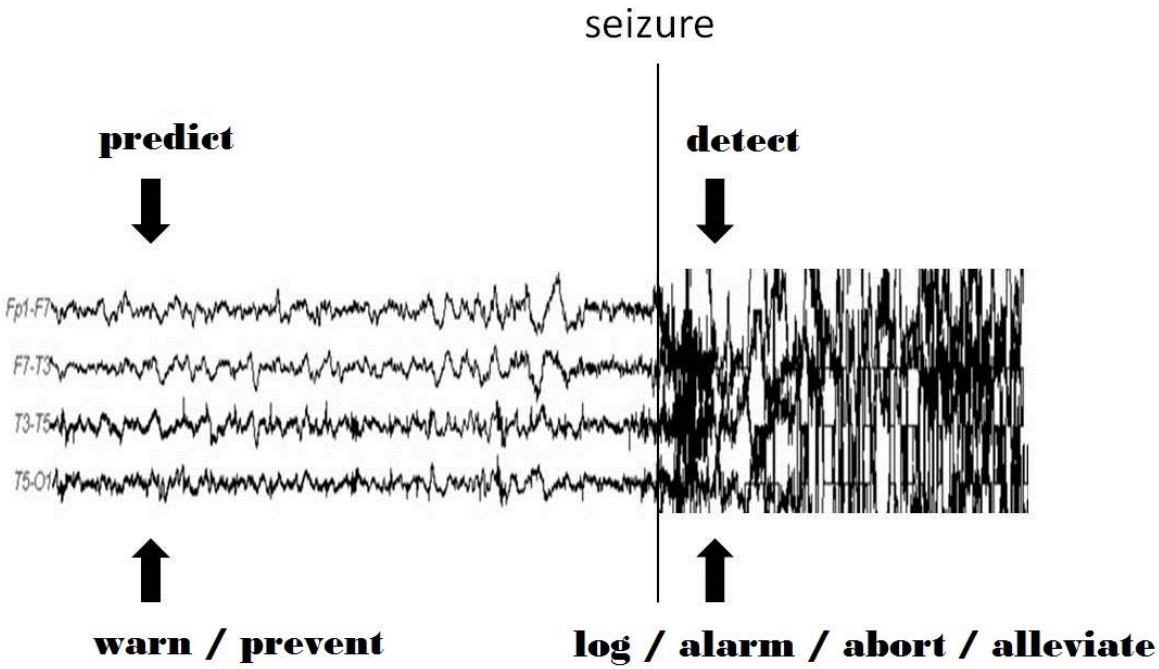
Introduction

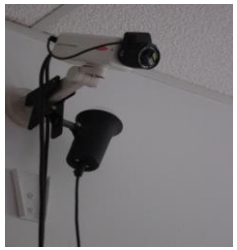
State Of The Art

User expectations

Challenges

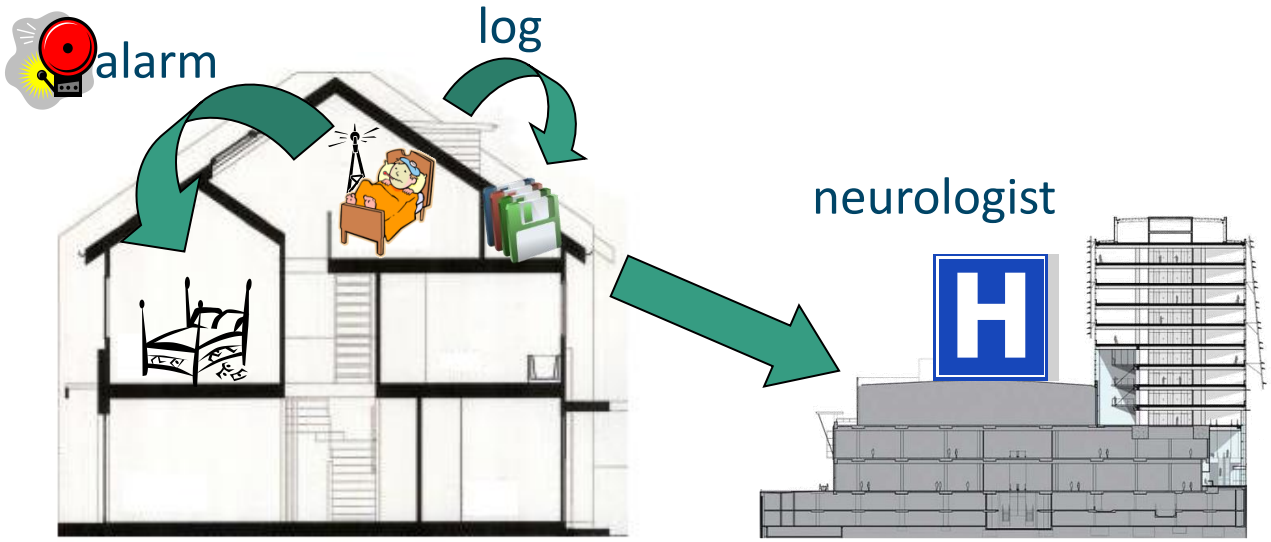
Seizure prediction vs. detection





Automatic seizure detection: possibilities

- Alert caregiver (medical & nonmedical intervention)
- Generating objective registry



- Possible understanding mechanisms SUDEP
- Offering reassurance, independence, sleep/life quality

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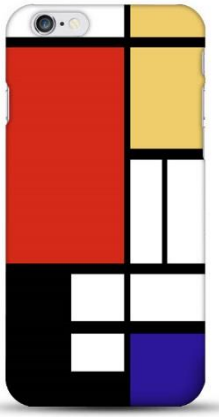

Detection methods: possibilities

			DETECTION METHODS							
			Audio	**Video**	**Electromagnetic waves**	**ACM/ gyro/ magneto**	**Electrodes**	**Plethys-mograph (volume)**	**Pressure**	**Tempe-rature**
NON-EEG SEIZURE MANIFESTATIONS	Motor	Body	bed noise	optical or thermal camera	radio, infrared or microwaves	bed or body attached	EMG		pressure mat for bed vacancy	
		Eye(lid)		optical camera			EOG/EMG			
	Autonomic	HR	PCG	thermal camera	radio or microwaves (BCG)	BCG	ECG	PPG (photoplethys mography)		
		BP						PPG		
		SpO_2			infrared waves of oximeter					
		Respiration	neck	thermal camera	radio or microwaves chest, infrared waves of oximeter/ capnograph	ACM/ magneto chest	EMG, EDR, impedance pneumograph chest, electrodes for pO_2/CO_2	RIP chest	pneumo-tachograph airflow	thermo-couple airflow
		Sweating					ohm/ galvanometer			
		Vomiting/ salivation/ coughing	audio phone				humidity meter			
		Incontinence					humidity meter			
	Vocalizations		audio phone							
	Fever			thermal camera	radio waves					sticker

MULTIMODAL

*Van de Vel et al. Non-EEG seizure-detection systems and potential SUDEP prevention: state of the art. Seizure 2013;22:345-355 & **Seizure** 2016;41:141-153*

Available devices (1)

Company	Device name	Detection method	Contact(less)	Seizures/events	Article	Website
Adris Tech-nologies (UK)	**PulseGuard** 	PPG for heart rhythm	Watch coupled to iPad	Unspecified	npf	http://www.pulseguard.org
Alert-It (UK)	**Ep-It Companion Monitor (S1029)**	Unspecified movement sensor, audio, moisture sensor, surface pressure	Under mattress (mat) and on mattress or under pillow sheet	TC and S, urination and vomiting, prolonged bed vacancy	npf	http://www.alert-it.co.uk
	Ep-It Guardian Monitor (P139) 	Unspecified movement sensor that can also detect respiration, audio, moisture sensor, surface pressure	Under mattress (mat) and on mattress or under pillow sheet	TC, S and complex seizures, abnormal breathing, urination and vomiting, prolonged bed vacancy, allows monitoring of up to 32 patients	npf	
Aremco (UK)	**Aremco** 	Respiration, audio, moisture, surface pressure	Under mattress plate	S	npf	http://www.disabilityworld.com/co/company.php?ID=3460
BioLert (Israel)	**EpiLert**	ACM for movement	Watch-like	TC, T, C	Kramer et al., 2011	http://www.biolertsys.com
Bioserenity (France)	**Neuronaute** 	ECG?, ACM?, EEG	Smart t-shirt & cap (the latter for EEG) coupled to smart phone	Unspecified	npf	http://www.bioserenity.com
Brain Sentinel (US)	**Brain Sentinel**	EMG	Device worn with strap on biceps	TC	Szabó et al., 2015	https://www.brainsentinel.com
Danish Care (Denmark)	**Epi-Care Free** 	ACM for movement	Bracelet	TC in adults and teenagers	Beniczky et al., 2013	http://danishcare.dk/dk
	Epi-Care 3000	ACM for movement	Affixed to mattress	Convulsions such as TC, S mainly in small children	npf	
D.C.T. Associates Pty Ltd (Australia)	**Vigil-Aide**	Unspecified vibration detection	Affixed to bed or worn in pouch/belt during day	Convulsions	npf	http://www.dctassociates.com.au/convul.htm
Emfit Ltd (Finland)	**Emfit Seizure Monitor** 	ACM for movement and respiration (even heart beating according to website), surface pressure	Under mattress mat	Convulsions such as TC and S, micro move-ments caused by breathing and heart beating, prolonged bed vacancy	Narechania et al., 2013; Van Poppel et al., 2013	http://www.emfit.com

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Available devices (2)

Company	Device name	Detection method	Contact(less)	Seizures/events	Article	Website
Empatica (US)	**Embrace** 	PPG for heart rhythm, EDA, temperature, ACM	Watch coupled to smart phone	TC, non-convulsive seizures such as CPS	Poh et al., 2012	https://www.empatica.com/embrace-watch-epilepsy-monitor
IctalCare A/S (Denmark)	**Eddi** 	EMG	ePatch attached to upper arm or leg	TC, T	Conradsen et al., 2012a; Larsen et al., 2014	http://www.ictalcare.dk
LivaNova (former Cyberonics, US)	**ProGuardian**	ECG + ACM	Chest worn patch & bedside hub	CPS, H	Sabesan et Sankar, 2015	http://ir.livanova.cyberonics.com/releasedetail.cfm?releaseid=728198
Livassured (Netherlands)	**NightWatch**	PPG for heart rhythm + ACM	(Upper) arm band	Nocturnal TC	npf	http://www.livassured.nl
Medpage (UK)	**MP5** 	Audio for movement (bed noises) and vocalizations, movement sensor	Under mattress	TC in patients weighing ≥ 12.7 kg	Carlson et al., 2009; Fulton et al., 2013	http://www.medpage-ltd.com
	ST-2 (out-dated)	Unspecified movement sensor (audio?) and surface pressure	Under mattress mat	TC & prolonged bed vacancy in patients weighing ≥ 12.7 kg	Fulton et al., 2013	
RTI International (US)	**RTI** 	ECG, respiration, temperature, body orientation, EDA, (EMG)	Torso band & bracelet (the latter for EDA)	TC (to a lesser extent T & M)	npf	http://www.rti.org/newsroom/news.cfm?obj=5C9D1803-AE4A-EE86-58351084319AA948
SAMi Alert (US)	**SAMi**	Video based movement detection, audio	Camera coupled to iPhone or iPad	Unspecified nocturnal motor seizures	npf	http://www.samialert.com
Sensorium (UK)	**Sensalert (200/SPTX-EP200)**	Unspecified movement sensor and optional moisture sensor	Under mattress	TC	npf	http://www.sensorium.co.uk
Smart Monitor Corp. (US)	**Smart-Watch** 	ACM for movement	Watch coupled to Android smart phone	Convulsive seizures mainly TC, C	Lockman et al., 2011; Patterson et al., 2015	http://www.smart-monitor.com
Vahlkamp (Netherlands)	**Epi-Watcher**	Unspecified movement sensor	Under mattress mat	TC	npf	http://www.vahlkamp.nl

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Conclusions

- Many devices available, but: few validated, missed seizures, false alarms, or conflicting results
- Apps for smart devices ↑
- International research
  - sensitivity 2 % - 100 %, False Detection Rate (FDR) per hour: 0 - 3
  - generalized convulsive to focal nonconvulsive seizures, day/night, adult/pediatric
- Gaps
  - no overview before ours, now already five: increasing interest
  - few multimodal
  - main focus on (typical) tonic-clonic seizures in adults
  - few possibilities to personalize

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Results (1)

	PC (N = 134)	MD (N = 21)
Experience	2 %	10 %
Usefulness / necessity	65 % (night)	85 % alarm (day/night), 62 % log
Performance requirements		
Correct detections	100 %	≥ 90 %
False detections	0 (1/seizure or 1/week)	2/w (high seizure freq) - 1/m (low)
Latency (seizure - alarm)	< 10 sec	2 - 5 min
Preferences		
Wearable	86 %	
Alarm type	Audio	Audio + video
Signal range	In house	Unlimited
Price	€ 250	€ 1000

Van de Vel et al. Automated non-EEG based seizure detection: do users have a say? Epilepsy Behav 2016;62:121-128

Results (2)

PC: important features

- Flexible, comfortable during sleep or seizure, discrete, wireless, water-/dirt-/shock-resistant…
  = comfort
- Easy to attach and operate, not easy to remove by patient, long battery life, coupling with smartphone…
  = user friendliness

MD: important focus

- Seizures to detect
  autonomic change (91 %) > fall risk (81 %) > intense movement (76 %)
- Body signals to monitor
  heart rhythm (86 %) > abnormal movement (67 %) > respiration (62 %)

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Conclusions

- Research should include all users (patients, caregivers, doctors) and focus on user requirements next to device development
- Need parents > patients ($p = 0.026$)
- Need ↑ for seizure frequency ↑ ($p = 0.001$);
  need ↑ for 43 % of those seizure free
- Focus
  - intense movement (TC, T, C, HFL), falls, heart rate changes (can indicate dangerous seizures)
  - 90% correct detections, 1 false alarm/seizure (1/week when seizure free)
  - wearable (day/night)
  - patient-specific settings

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10 years of research (1st study 2005), no ideal system, **reasons?**

- Which events to detect?
- Day versus night?
- Inter- & intrapatient variability?
- Which/how much/placement sensors?
- Desired features/options?

➡ suboptimal at purchase but adapt to patient characteristics (weight, steady state heart rhythm), seizures (type, intensity, duration) and wishes: personalization!

Ethical considerations

- Privacy & data safety
- Burden of responsibility family & caregivers
- False sense of (100%) security

Thank you!