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Multimodal seizure detection

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on behalf of the TeleEpilepsy Study Group


Dravet
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Kempenhaeghe


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ZonMw


Epilepsiefonds
De Macht van het Kleine


STICHTING ZIE
ZorgIntensief & Epilepsie


TU/e
technische
universiteit
eindhoven

financial disclosure

TeleEpilepsy has an agreement with LivAssured that future profits from NightWatch will result in research donations from LivAssured.

Nobody from the TeleEpilepsy consortium has any direct financial links with LivAssured, or holds shares.

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Ratio of multimodality

- better sensitivity
- less false positives
- less tuning
- more seizure types
- fall out of a modality

Downside

- user friendliness
- wearability
- tolerance
- interference
- battery life
- heating
- cost
- overdetection

Algorithm

- 1+1+…
- physiology based

  e.g. HR↑ followed by ACC↑ = seizure
- multiple classification

  e.g. machine learning

  partly physiology-based
- deep learning
- self-learning

Modalities in practice

examples:	physiology			sensor types	wearable yes/no
	movement	muscle tone	autonomic		
HR+ACC+EMG	x	x	x	3	y
HR+oxymetry			x	1	y
ACC+videoframe analysis	x			2	y+n
HR from pletysmography and radar			x	2	y+n
videoframe analysis+audio	x			2	n

Evaluation stages

trials:

- in video-EEG monitoring unit
  - gold standard: video-EEG
- in institutionalized care
  - neurology ward
  - long-stay facility
    - gold standard: video, nurse satisfaction
- at home
  - gold standard: QoL, caregiver satisfaction

Published evidence multimodal systems

• Conradsen 2010/2012	ACC + EMG
• Milosevic 2016	ACC + EMG
• Poh 2012	ACC + EDA
• Van de Vel 2016	ACC + video + radar
• Sarkic 2015	HR + EDA
• Goldenholz 2017	HR + OXY
• Cogan 2015	HR + ACC + EDA + OXY
• Arends (t.b.p.)	HR + ACC (+ video + audio)

Conclusion

- focus on movement and autonomic response (heart rate)
- multiple sensor types
- none is completely non-wearable

Results

		n	type	%sens	FDR/night (8 h)	algorithm	inclusion bias
Conradsen	DK	5	TC, C, M	91-100	0.64	ML	y
Milosevic	B	56	TC	91	0.33	ML	y
Poh	US*	80	TC	94	0.25	ML	some
Van de Vel	B	1	TC, C, T	56	20	ML?	n
Sarkis	US*	20	TC			physiol	y
Goldenholz	US	45	TC	81	9.6	physiol	y
Arends	NL	28	TC, T, C, M, HK	86	0.46	physiol	n

Conclusion

- focus on TC seizures
- generally good sensitivity
- wide range of false detections
- almost all studies overestimate sensitivity because the algorithm was developed on the same set of patients (bias)

Added value

- Poh 2012, TC

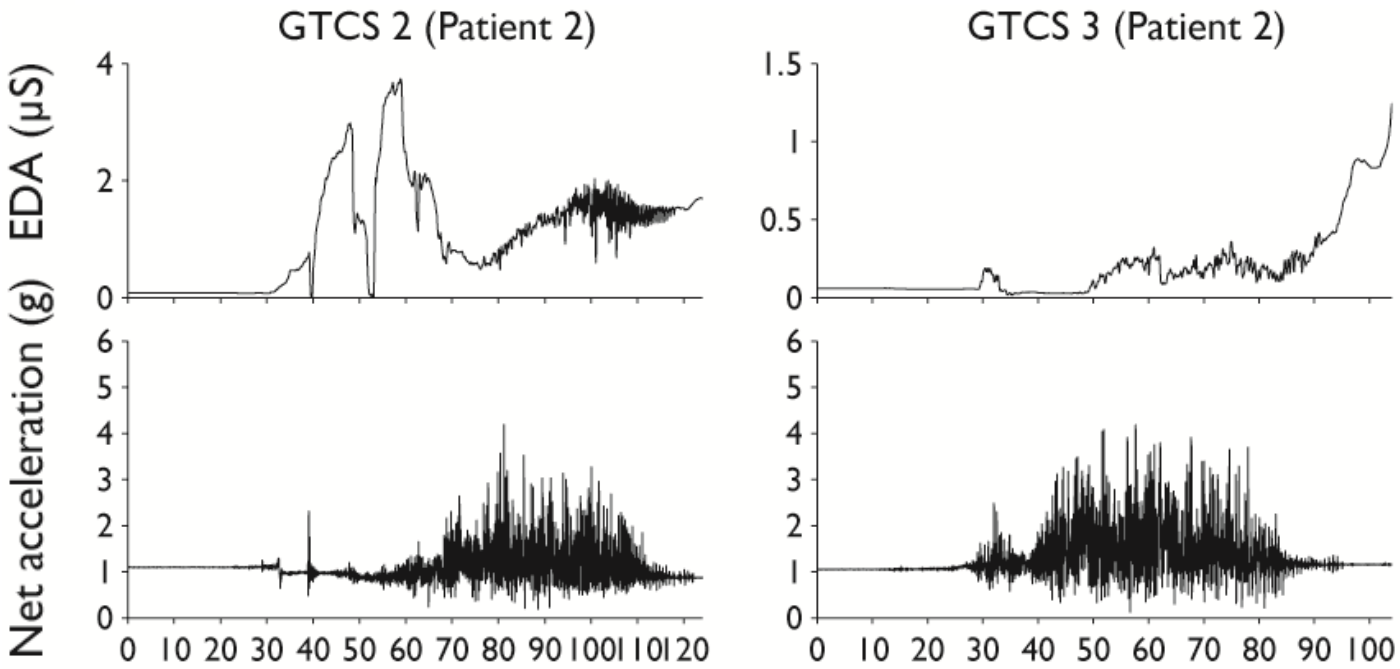
	SmartWatch	Epilert	MIT Biosensor
modality	ACC	ACC	ACC+EDA
n	40	31	80
sensitivity	88 (7/8)	91 (20/22)	94 (15/16)
FDR (/8 h)	?	(0.04)	0.25

Added value

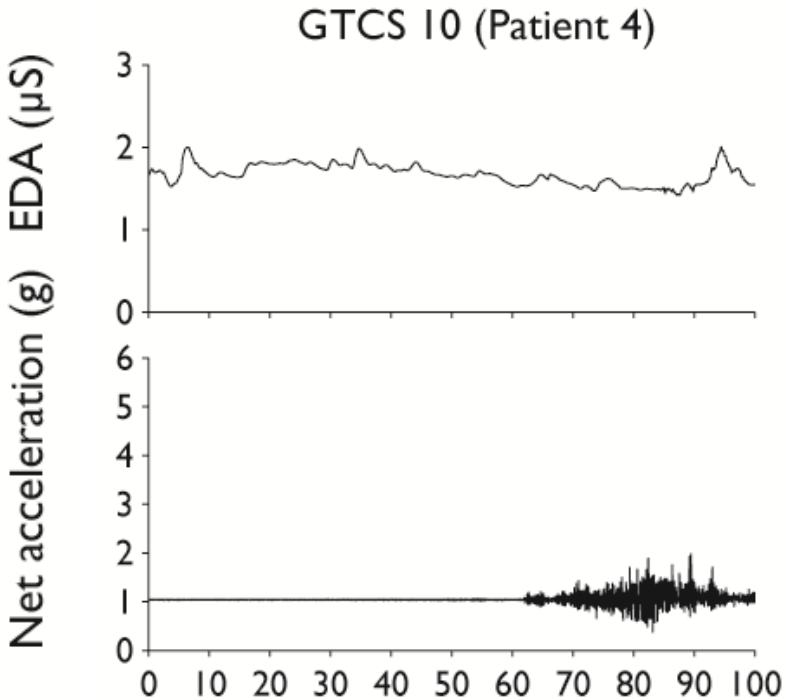
- Milosevic 2016, TC, n=56

	unimodal			multimodal
	4ACC	2ACC	EMG	ACC+EMG
%sens	73	86	81	91
FDR (/8 h)	0.7	1.3	4.8	0.3
latency (s)	16	19	11	11

Examples



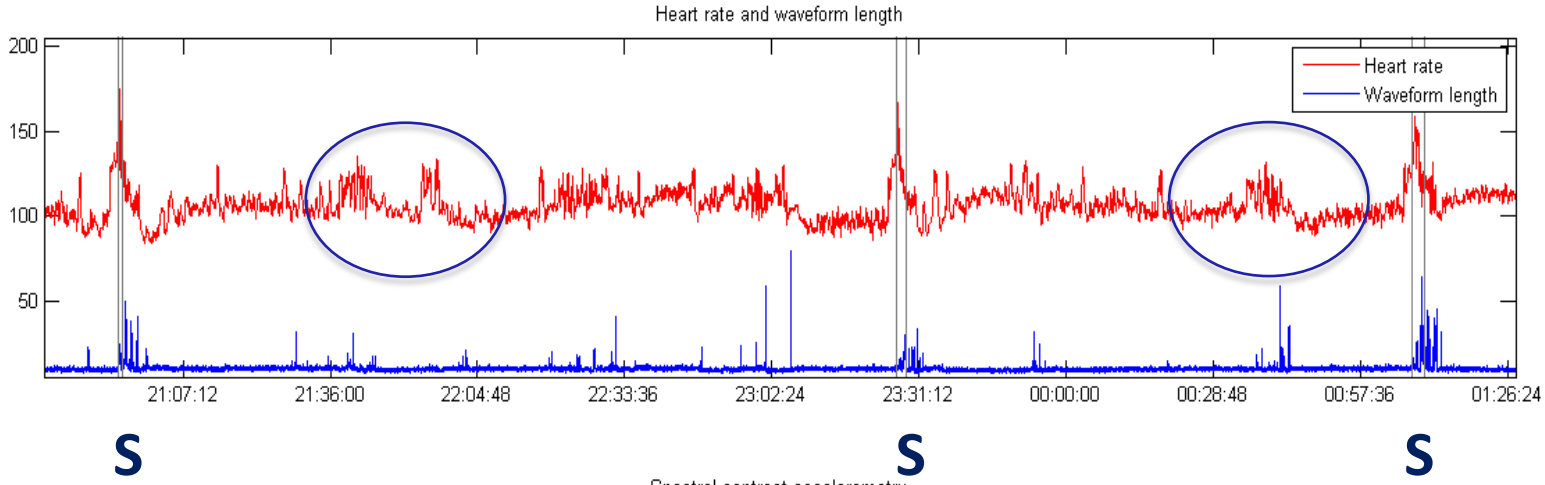
Poh, Epilepsia 2012



Poh, Epilepsia 2012

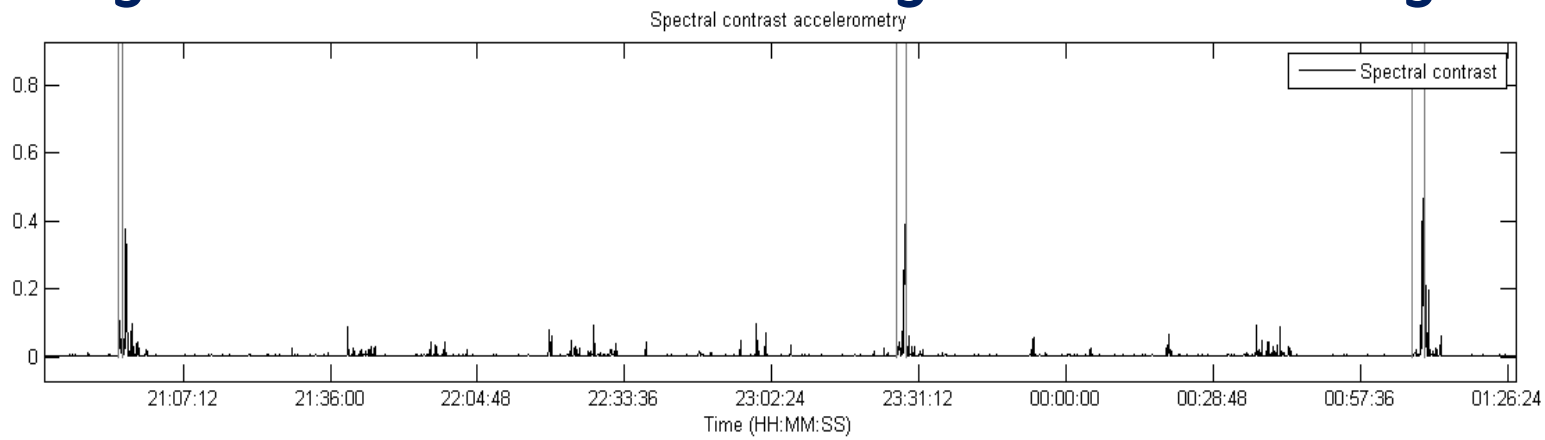
Examples

HR



S S S

ACC



Van Andel (tbp)

Conclusion

systems that use different sensors may:

- improve sensitivity
- reduce false detections
- have better latency

but require difficult algorithms

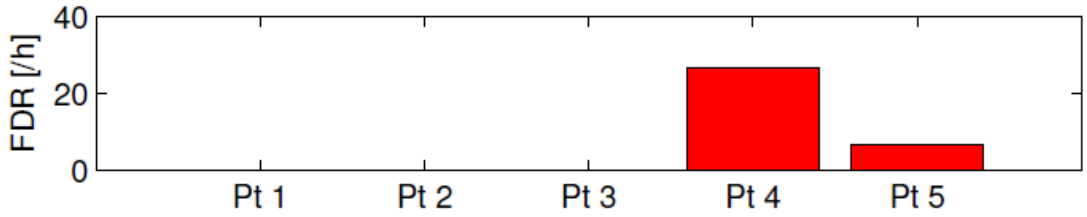
Remark 1 – seizure types

- Nightwatch, HR + ACC, **'major motor seizure'**

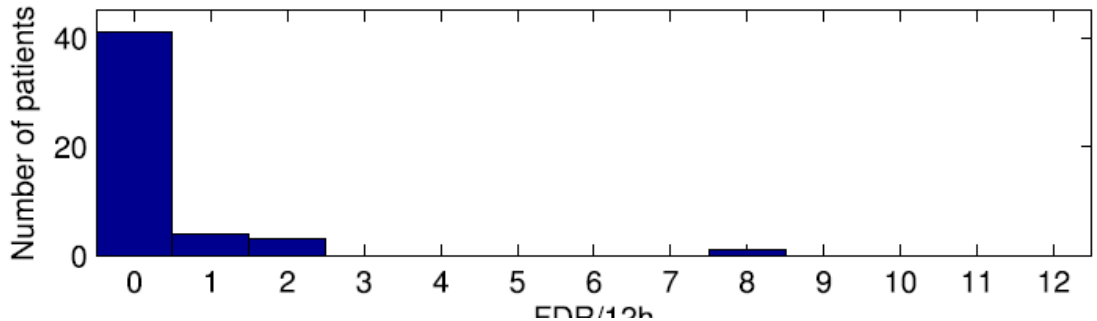
	tonic-clonic	tonic	hyper-kinetic	cluster
N	**22**	**11**	**5**	**14**
Median	**96%**	**89%**	**73%**	**84%**
Min	**63%**	**0%**	**50%**	**0%**
Max	**100%**	**100%**	**100%**	**100%**

Arends (tbp)

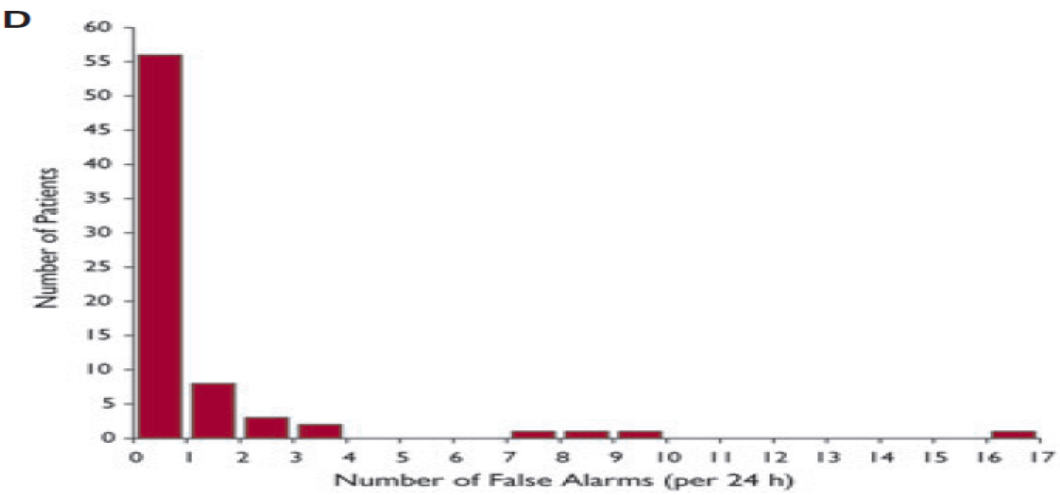
Remark 2 – generic or personalized?



Conradsen 2010



Milosevic 2016



Poh 2012

generic or personalized?

- our experience (HR + ACC)
  - 15-20% of patients account for >90% of false detections
  - same for ACC + EMG (Conradsen/Milosevic)
  - same for ACC + EDA (Poh)

→ consequences?

Final conclusions

- future is in multimodal systems
- generic algorithms remain the goal
- probably 15-20% of patients defy generic algorithms
- focus on major motor seizures, not just TC seizures (“caregiver in mind”)
- studies should avoid inclusion bias
- studies should go into the field

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