Received: 17 October 2019 | Accepted: 18 October 2019

DOI: 10.1111/epi.16393

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GRAY MATTERS

Letter

Critical remark on the "heart rate differential method"/"HR-diff" parameter

We read with much interest the recently published article by Jeppesen and colleagues on seizure detection based on heart rate variability.[1] We are concerned because it presents an algebraic quandary in its basic formula, which challenges the interpretations of the results of the "HR-diff" parameter. This quandary was also present in an earlier publication from this group[2] but was not previously challenged.

The authors claim to average or sum up the so-called "heart rate differential method" over 50 or 100 (in the formula k) R-R intervals using the following equation:

$$\mathrm{HR-diff} = \sum_{i=0}^{k} \frac{1}{2}\left(x_{(i+1)} - x_{(i-1)}\right)$$

As a result of the subtraction of two R-R intervals in each summand of the formula, all R-R intervals except the first two and last two will disappear mathematically, whatever value they may have:

$$= \frac{1}{2}\left(\sum_{i=0}^{k} x_{(i+1)} - \sum_{i=0}^{k} x_{(i-1)}\right)$$

$$= \frac{1}{2}\left(\sum_{i=1}^{k+1} x_{(i)} - \sum_{i=-1}^{k-1} x_{(i)}\right)$$

$$= \frac{1}{2}\left(x_k + x_{k+1} + \left(\sum_{i=1}^{k-1} x_{(i)}\right) - \left(\sum_{i=1}^{k-1} x_{(i)}\right) - x_{-1} - x_0\right)$$

$$= \frac{1}{2}\left(x_k + x_{k+1} - x_{-1} - x_0\right)$$

$$= \frac{(x_k + x_{k+1})}{2} - \frac{(x_{-1} + x_0)}{2}$$

Taking into account that $x_k \equiv t_k - t_{k+1}$, where t_k is the time of the k-th heartbeat, we come to the simple derivation:

$$\mathrm{HR-diff} = \frac{\left(t_{k+1} - t_{k-1}\right)}{2} - \frac{\left(t_0 - t_{-2}\right)}{2}$$

Following the shown simplification, this procedure results in only the total R-R interval change over the given number of about k (50 or 100) heartbeats. This, therefore, does not represent the heart rate variability, as it only shows the cumulative effect over time. This will lead to a different interpretation of the results as an "average" or "smoothing" of many intervals does not occur using this formula (except for the trivial averaging of two successive R-R intervals). As could then be expected, this parameter scores badly (visible in Figure 2 in [1]) while this parameter scores better after prefiltering, which enables the possibility to place information from more than the four remaining arbitrarily chosen R-R intervals (-1;0;k;k+1) into the parameter.

Therefore, the parameter "HR-diff" does not allow relevant smoothing or averaging on its own and only prefiltering enables some averaging/smoothing. Thus this parameter should be simplified as shown above to save some computational power, and the sum-formula should no longer be used as it stands.

CONFLICT OF INTEREST

Neither of the authors has any conflict of interest to disclose. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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REFERENCES

1. Jeppesen J, Fuglsang-Frederiksen A, Johansen P, Christensen J, Wüstenhagen S, Tankisi H, et al. Seizure detection based on heart rate variability using a wearable electrocardiography device. Epilepsia. 2019;60(~~10~~):2105–13.
2. Jeppesen J, Beniczky S, Johansen P, Sidenius P, Fuglsang-Frederiksen A. Detection of epileptic seizures with a modified heart rate variability algorithm based on Lorenz plot. Seizure. 2015;24:1–7.

Received: 24 October 2019 | Accepted: 28 October 2019

DOI: 10.1111/epi.16391

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GRAY MATTERS

Letter

In response: Heart rate differential method simple but inefficient method for seizure detection

To the Editors,

We wish to thank Widman and colleagues for their interest in our recent publication on seizure detection based on heart rate variability.[1]

We agree that the equation of HR-diff can be rewritten as spelled out in the comment. However, we see no quandary in the original equation as it is written in both this and in an earlier publication,[1,2] since it clearly defined the result. The HR-diff equation can be written in the way we originally presented it in the papers[1,2] or rewritten as Widman and colleagues have done. However, we do not believe that one way is "better" than the other because each is simply just another way of writing the formula. Thus, we see no reason why the HR-diff parameter should not be written as we originally defined it.

The HR-diff is a parameter that we stated in[2]: "simply computes the positive rate of heart rate change within the given window." We used this parameter in both papers to compare this simplest form of computing heart rate change (HR-diff) against more advanced heart rate variability methods (ModCSI and CSI).

In the comments by Widman and colleagues, they state that: "As could then be expected, this (HR-diff) parameter scores badly (visible in figure 2) while this parameter scores better after prefiltering, which enables the possibility to place information from more than the four remaining arbitrarily chosen R-R intervals $(-1;0;k;k+1)$ into the parameter."

First, seizure detection based on heart rate changes as the simple change in pulse-rate or R-R time-length within a given time- or R-R interval window length has been the method of choice in several papers analyzing seizure detection. Therefore, we opted to assess this aspect too. The explanation for the poor performance of this parameter is probably not related to any physiologic issues but rather to some few misplaced R-peak detections (noise) during baseline data of the patients, which can create too high a threshold for seizure detection in the test data. The algorithm with prefiltering before calculating HR-diff (HR-diff-filtered) confirm this suggestion, as it filters out outliers (noise) and preforms much better than HR-diff without pre-filtering. However, still the more advanced ModCSI and CSI algorithms performs better than any stand-alone HR-diff algorithm with or without prefiltering in our analyses of the test data.

Second, the four R-R intervals in the equation are not "arbitrarily" chosen. They have k-length difference (window length: 50 or 100 R-R interval lengths), which, as stated, simply computes the positive rate of heart rate change within the given window. We have never stated that the HR-diff method is using averaging/smoothing as suggested in the comments by Widman and colleagues.

CONFLICT OF INTEREST

Neither of the authors has any conflict of interest to disclose. We confirm that we have read the Journal's position on issues involved in ethical publication and affirm that this report is consistent with those guidelines.

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REFERENCES

1. Jeppesen J, Fuglsang-Frederiksen A, Johansen P, Christensen J, Wüstenhagen S, Tankisi H, et al. Seizure detection based on heart rate variability using a wearable electrocardiography device. Epilepsia. 2019;60:2105–13.
2. Jeppesen J, Beniczky S, Johansen P, Sidenius P, Fuglsang-Frederiksen A. Detection of epileptic seizures with a modified heart rate variability algorithm based on Lorenz plot. Seizure. 2015;24:1–7.

DOI: 10.1111/epi.16404

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Announcements

A Tribute to Fred Andermann

4–5 December 2019
Montreal Neurological Institute & Hospital, Canada
https://www.ilae.org/congresses/a-tribute-to-fred-andermann

American Epilepsy Society

6–10 December 2019
Baltimore, MD, USA
https://meeting.aesnet.org/abstracts

10th EPODES Advanced II Paediatric Epilepsy Surgery, Palliative surgery & Neuromodulation

20–24 January 2020
Czech Republic
http://www.ta-service.cz/epodes2020/

1st Regional Autism Conference (RAC2020)

24–26 January 2020
Muscat, Oman
https://autism2020.org/

2020 British Paediatric Neurology Association (BPNA) Annual Conference

29–31 January 2020
Belfast, Northern Ireland
https://bpna.org.uk/conference/2020/

14th Escuela Latino Americana de Verano de Epilepsia (LASSE)

27 February–6 March 2020
São Paulo, Brazil
https://lasse.med.br/

2020 Epilepsy Review Course and Best Practices

4–6 March 2020
Cairo, Egypt
Information: https://www.ilae.org/congresses/2020-epilepsy-review-course-and-best-practices

EEG in the First Year of Life -- from newborn to toddler

6–8 March 2020
Kerala, India
Information:https://www.ilae.org/congresses/eeg-in-the-first-year-of-life1

7th International Conference on Non-Invasive Brain Stimulation (NIBS)

24–26 March 2020
Baden-Baden, Germany
https://www.nibs-conference.de/

64. Jahrestagung der Deutschen Gesellschaft für Klinische Neurophysiologie und Funktionelle Bildgebung (64th annual meeting of the German Society of Clinical Neurophysiology)

26–28 March 2020
Baden-Baden, Germany
https://www.dgkn-kongress.de/

14th World Congress on Controversies in Neurology (CONy)

26–29 March 2020
London, UK
http://cony.comtecmed.com/

3rd International Training Course on Neuropsychology in Epilepsy

29 March–3 April 2020
Bordeaux, France
Information: https://www.ilae.org/congresses/3rd-international-training-course-on-neuropsychology-in-epilepsy

Epilepsy 2020: A vision of the future in epilepsy research

8–9 May 2020
Montreal Neurological Institute-Hospital, Canada
https://www.ilae.org/congresses/epilepsy-2020-a-vision-of-the-future-in-epilepsy-research

International Training Course on Neuroimaging of Epilepsy

14–17 May 2020
Montreal, Canada
Course website: https://www.mcgill.ca/neuro/events/international-training-course-neuroimaging-epilepsy

XI Congreso Latinoamericano de Epilepsia

23–26 May 2020
Medellín, Colombiax
Website: https://www.epilepsycongress.org/lace/

Fifteenth Eilat Conference on New Antiepileptic Drugs and Devices (EILAT XV)

June 7-10, 2020
Madrid, Spain
https://www.eilatxv.com

55. Jahrestagung der Deutschen Gesellschaft für Epileptologie (DGfE) 55th Annual Meeting of the German Society of Epileptology

10–13 June 2020
Breisgau, Germany
https://www.epilepsie-tagung.de/

38º Congresso da Liga Brasileira de Epilepsia – Curitiba 2020

10–13 June 2020
Curitiba, Brazil
http://epilepsia.org.br/evento/38o-congresso-liga-brasileira-de-epilepsia-curitiba-2020/

21st Annual Meeting of Infantile Seizure Society International Symposium on Pathophysiology of Developmental and Epileptic Encephalopathy (ISSET)

19–21 June 2020
Okayama, Japan
Website: https://www.emedevents.com/c/medical-conferences-2020/the-21st-annual-meeting-of-infantile-seizure-society-international-symposium-in-pathophysiology-of-developmental-and-epileptic-encephalopathy

14th European Congress on Epileptology (ECE)

5–9 July 2020
Geneva Switzerland
Website: http://www.epilepsycongress.org/ece/

ESTM 2020: Epilepsy Surgery Techniques Meeting

9–10 July 2020
Geneva, Switzerland
https://www.estm2020.com/

Dianalund Summer School on EEG & Epilepsy 5th edition

12–18 July 2020
Dianalund, Denmark
https://www.ilae.org/congresses/5th-dianalund-summer-school-on-eeg-and-epilepsy

2020 Advanced San Servolo Epilepsy Course Bridging Basic with Clinical Epileptology - 7: Accelerating Translation in Epilepsy Research

20–31 July 2020
San Servolo (Venice), Italy

https://www.ilae.org/congresses/2020-advanced-san-servolo-epilepsy-course

14th Baltic Sea Summer School on Epilepsy (BSSSE 14)

9–15 August 2020
Sigulda, Latvia
https://www.ilae.org/congresses/14th-baltic-sea-summer-school-on-epilepsy-bssse-14

Approaching Complexity in Neuroscience and Epilepsy Mechanisms of Epilepsy and Neuronal Synchronization

15–16 August 2020
Castelldefels, Spain
https://www.grc.org/mechanisms-of-epilepsy-and-neuronal-synchronization-grs-conference/2020/

Molecular and Network Complexity in the Epileptic Brain Mechanisms of Epilepsy and Neuronal Synchronization

16–21 August 2020
Castelldefels, Spain
https://www.grc.org/mechanisms-of-epilepsy-and-neuronal-synchronization-conference/2020/

11th Summer School for Neuropathology and Epilepsy Surgery (INES 2020)

10–13 September 2020
Erlangen, Germany
https://www.ilae.org/congresses/11th-international-summer-school-for-neuropathology-and-epilepsy-surgery-ines-2020

First North American Epilepsy Congress (NAEC)

25–27 September 2020
Toronto, Canada
Website: https://www.epilepsycongress.org/naec/

13th Asian and Oceanian Epilepsy Congress (AOEC)

8–11 October 2020
Fukuoka, Japan
Website: https://www.epilepsycongress.org/aoec/

34th International Epilepsy Calendar

28 August–1 September 2021
Paris, France
Website: https://www.epilepsycongress.org/iec/