Mathematical Assessment of Diabetic Autonomic Dysfunction

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A new mathematical method was previously proposed to assess the sympathovagal balance on a beat-to-beat basis. Based on Scale Covariance, this method extracts information on the state of the sympathetic and parasympathetic subsystems of the Autonomic Nervous System, from the R-R time-intervals of the ECG.The measure given is that of a point-particle trajectory whose position describes the overall state of the Autonomic Nervous System, whereas calculated indices give activity degrees of subsystems locally.

We propose to investigate the application of this measurement to the evaluation of Diabetic Autonomic Neuropathy. Investigation is limited to first validation through a non-ambiguity test, a stability test under time scale changes, a comparison with existing autonomic scoring, and coherence with clinical observations.
Recordings on 30 patients (mean age: 47 years; with recorded enlightened consent) were performed in supine condition for 10 minutes; Autonomic manoeuvres (such as Respiratory Sinus Arrythmia, Valsalva manoeuvre, tilt test) were also performed for scoring, following Bellavere et al.

RESULTS:

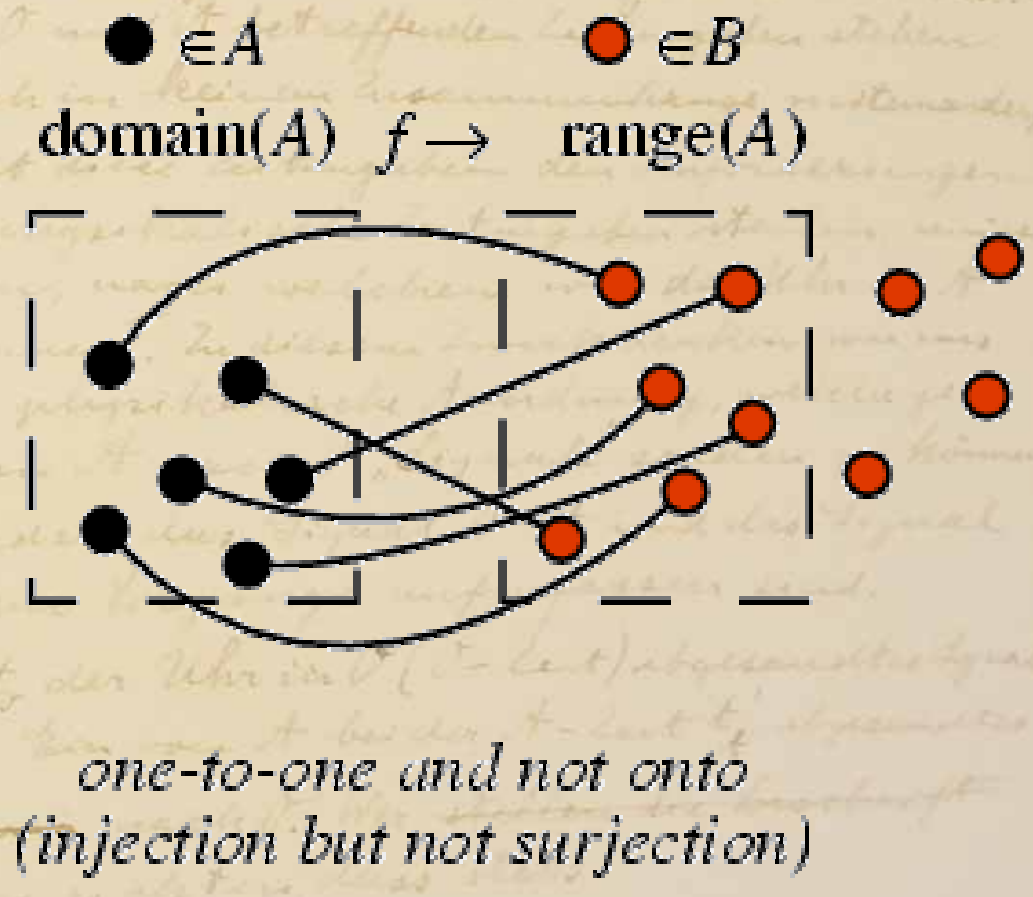
The definition of Autonomic Dysfunction, as lack of coupling of sympathetic and parasympathetic indices, proves sound in light of results which suggest that for such a measurement, no overlap would exist between cases of absence and presence of Diabetic Autonomic Neuropathy. Patients are ordered by measure into clear-cut groups, which stay stable under change of the observation-window (500 RR intervals in supine is proved sufficient) and without contradicting clinical observations. None of this was previously possible with autonomic scoring. Supine conditions remain the optimal conditions for measuring dysautonomia.

CONCLUSION:

Accurate assessment of DAN would be possible in about five minutes, for a patient at rest. Results infer a pure discrimination between healthy and autonomic neuropathy cases, allowing for the definition of early cases, early in detection and presence. A further study should investigate the universality of values which demarcate the groups.

Ideal definition of Autonomic Dysfunction

- Well defined, i.e.
  $(x=y)\Rightarrow(f(x)=f(y))$
- Whereas
  $(f(x)=f(y))\Rightarrow(x=y)$
  means injective
- Ability to distinguish the aftermath of an atropine injection from a parasympathetic failure



Autonomic Dysfunction

- What is a well functioning ANS ?
- Good interaction between systems
  - Beyond antagonism of the subsystems
  - Interaction in Physics... Inter-action
  - Acts on the same thing/level
    - Things here are ***events***
- Simultaneity of events

Relativity of Simultaneity

$$t_1' = \frac{t_1 - (v x_1 / c^2)}{\sqrt{1 - v^2/c^2}}$$

$$t_2' = \frac{t_2 - (v x_2 / c^2)}{\sqrt{1 - v^2/c^2}}$$

$$t_2' - t_1' = \frac{(t_2 - t_1)}{\sqrt{1 - v^2/c^2}} + \frac{v}{c^2 \sqrt{1 - v^2/c^2}} (x_1 - x_2)$$

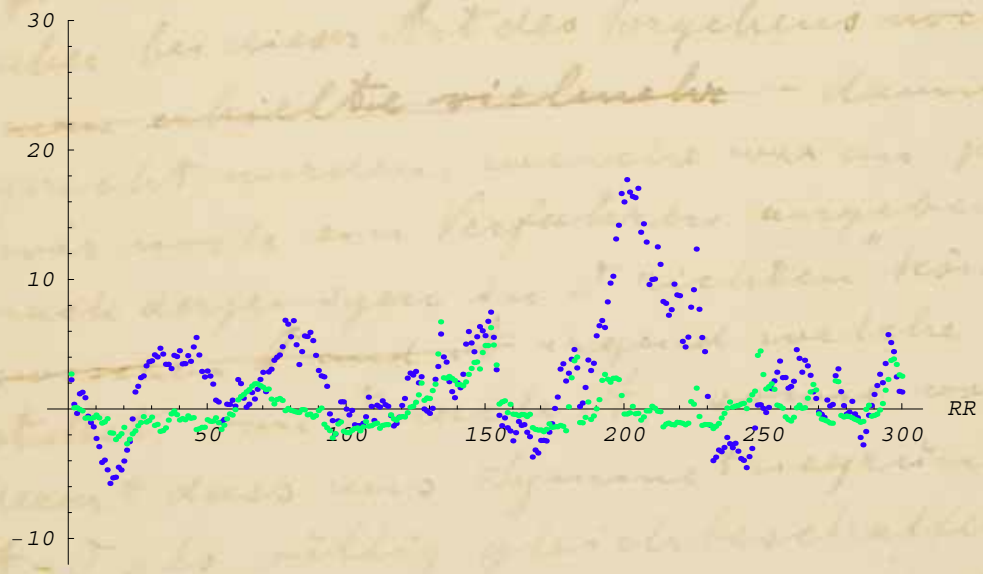
Two events, which are simultaneous with respect to one frame of reference, are not in general simultaneous with respect to another frame of reference which is in relative motion with respect to the previous frame...
unless the two events happen at the same *confounded position* !

Einstein to Bergson

Paris, April 6th 1922

The question is therefore posed as follows: is the time of the philosopher the same as that of the physicist? The time of the philosopher is both physical and psychological at once; now, physical time can be derived from the time of consciousness. Originally individuals have the notion of the simultaneity of perception; they can hence understand each other and agree about certain things they perceive; this is a first step toward objective reality. But there are objective events independent of individuals, and, from the simultaneity of perceptions one passes to that of events themselves. In fact, that simultaneity led for a long time to no contradiction due to the high propagational velocity of light. The concept of simultaneity therefore passed from perceptions to objects. To deduce a temporal order in events from this is but a short step, and instinct accomplished it. But nothing in our minds permits us to conclude to the simultaneity of events, for the latter are only mental constructions, logical beings. Hence there is no philosopher's time; there is only a psychological time different from the time of the physicist.

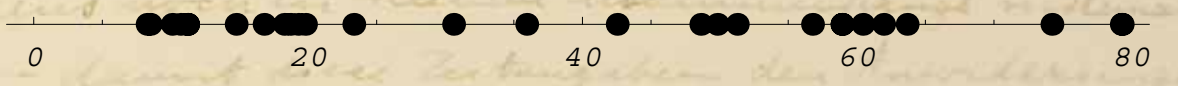
Beat-to-Beat ANS measurements

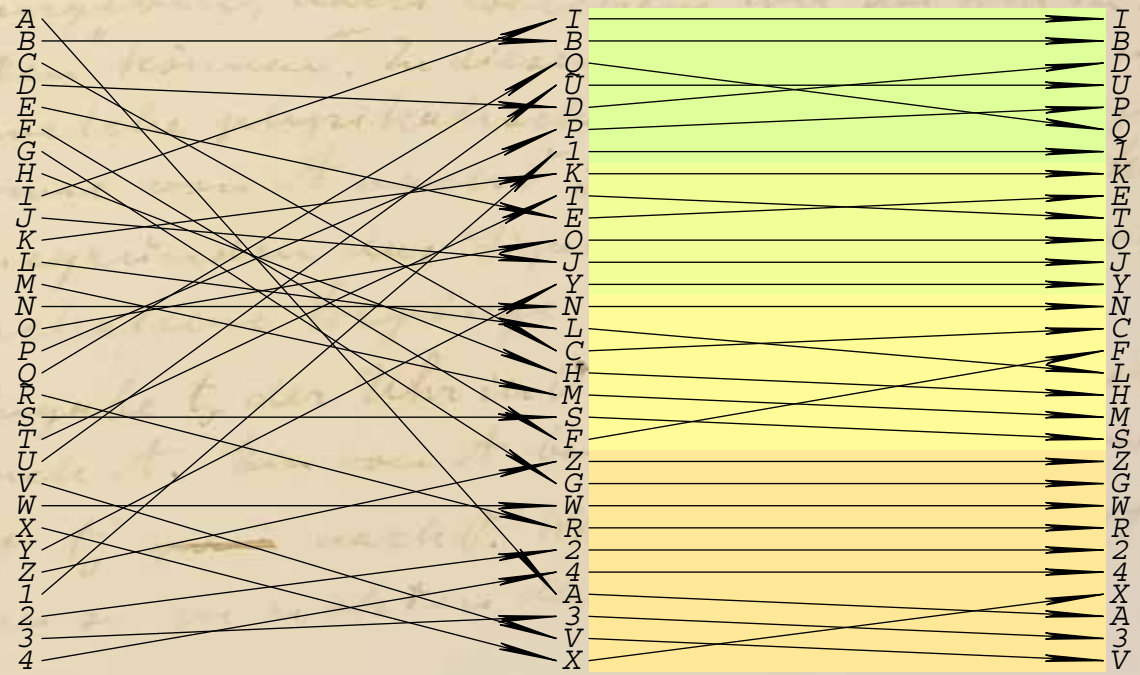


- Confounded SP&PSP indices when systems work well together
  - Seen from SP, PSP advances at a constant velocity
  - Closed scale (-50 till 50) found for degrees of activity (just like the limiting velocity c)
- Autonomic Dysfunction as lack of coupling

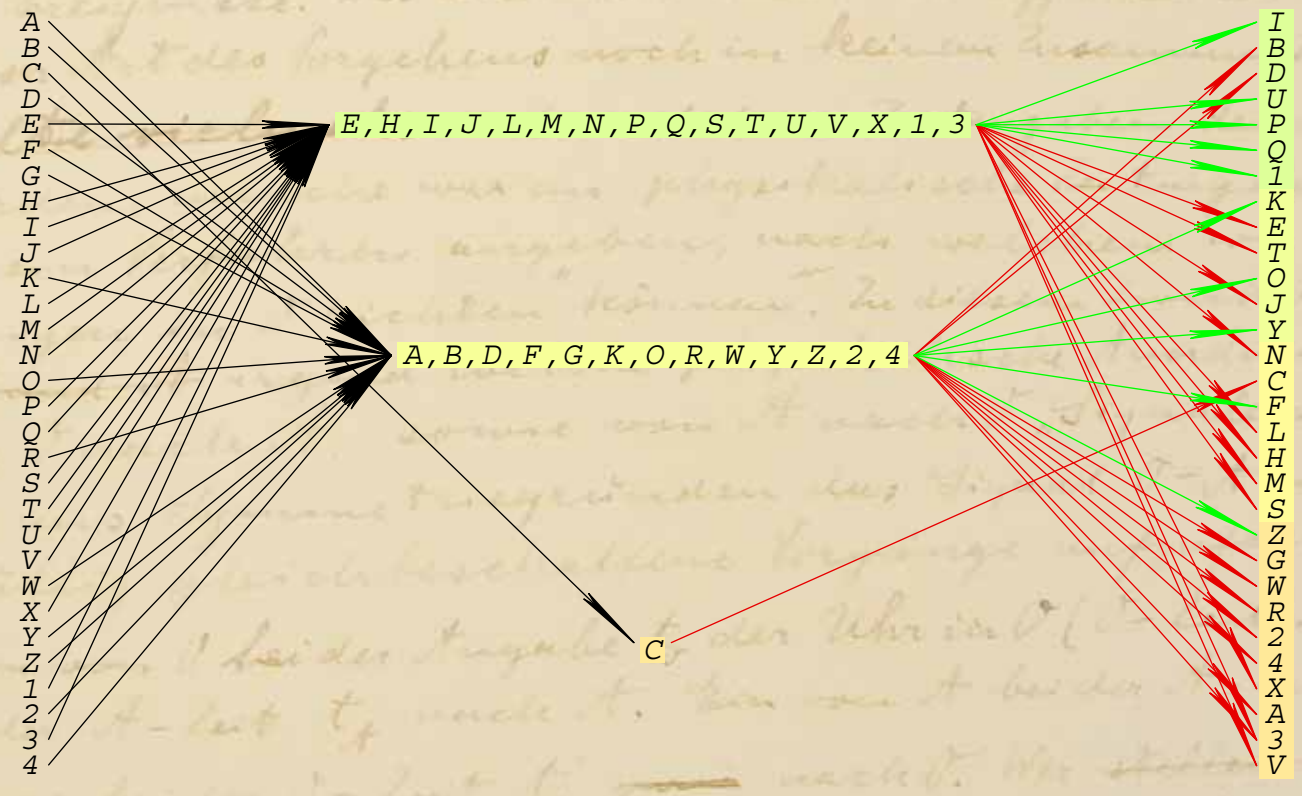
Clinical Study on 30 diabetic patients

- Clear-cut groups
  - Accumulation points
  - No overlaps
- Stability of groups under change of the measurement window

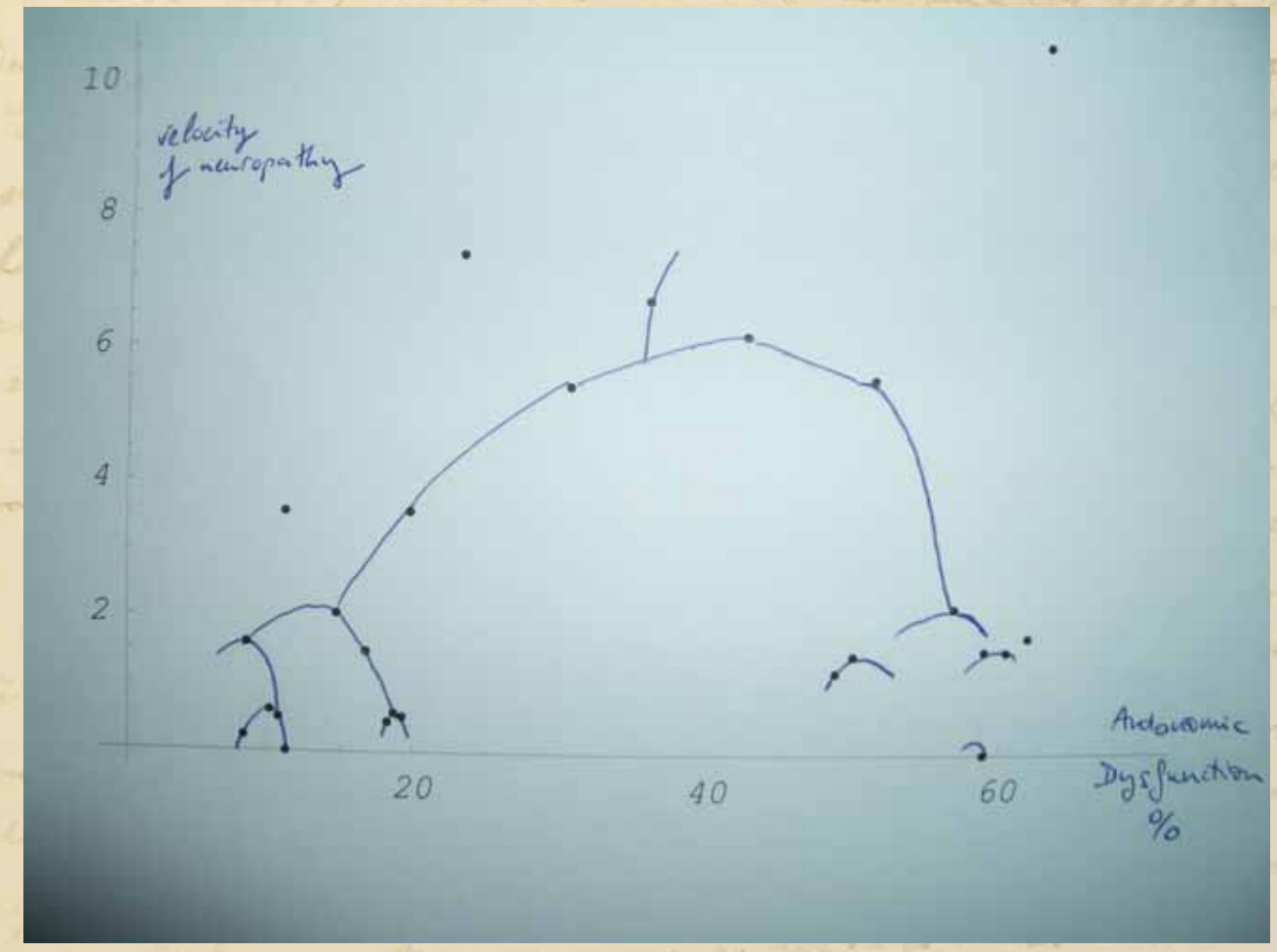




Comparing with Autonomic Scoring



Let us dream a bit...



... about reversibility