Entropy and multifractality in heart rate dynamics as markers of specific brain-heart coordinations when adapting to cognitive tasks

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Recent works based on the neuro-visceral integration model [1] have underlined the potential of the heart rate variability (HRV) dynamics to account for cognitive-emotional state. People exposed to a stressful environment or performing a cognitive demanding task exhibit adaptive coordination across brain-heart interconnections, spanning several scales of space and time. Non-invasive measurements of HRV have been shown helpful in quantifying these complex interconnections. Our recent works [2] emphasize the added value of HRV entropy to follow up emotional reactions of subjects performing a cognitive task under mild stress. Another non-linear approach, multifractal dynamic computation of HRV reflects the adaptation of systems in response to a changing environment [3]. The aim of the present study was to associate HRV complexity to cognitive functioning of subjects exposed to specific cognitive tasks.

Thirty-six healthy volunteers (20 males, 16 females) were included in this study. After a quiet phase watching a movie (*Baseline*), they performed three randomized cognitive tasks (*GO-noGO*(GNGT), *stop signal*(SST), *Stroop*(SCWT)), while HRV was recorded using a Polar H10 chest strap.

Non-linear HRV indices, refined composite multiscale entropy [4] and multiscale multifractal index [5] were computed with custom-designed algorithms to reveal entropy and fractal properties of cardiac signals. HRV time series were also analyzed in temporal (RMSSD) and frequency (HF, LF) domains.

While classical time and frequency domain indices failed to distinguish specific cognitive challenges, complexity indices add significant value for interpretative hypotheses.
HRV entropy was higher during SCWT task compared to *Baseline* ($p \leq 0.001$) and to other tasks, GNGT ($p \leq 0.05$) and SST ($p \leq 0.01$), which might indicate better coordinated brain-heart interconnections.
A greater multifractality at specific observational scales during SST task (*Baseline* ($p \leq 0.05$), GNGT task ($p \leq 0.01$)) suggests a different restructuration of central networks.

Entropy and multifractal markers may distinctively reflect adaptive cognitive-autonomic architecture, as illustrated by the specific executive functions associated with our experimental cognitive tasks. This has interesting consequences in human monitoring situations where direct brain measurements can hardly be conducted. The present results comfort the idea that non-linear HRV indices are helpful in follow-up of athletes and might extend to patients to distinguish disturbed psycho-emotional and cognitive states.

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