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APPLYING ENTROPY TO HUMAN CENTER OF FOOT PRESSURE DATA TO ASSESS ATTENTION INVESTMENT IN BALANCE CONTROL

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Postural control and stability of a person is a very strong information on his/her autonomy and his/her wellbeing

- Control of balance involves the integration of sensory information from various sources including visual, somatosensory and vestibular systems
 - Young and healthy person \rightarrow minimum attention request for this task

Changes in the conditions of acquisition (typically degradation) of these information will also change the automaticity of postural control → more attention required for task.

► Changes can also be due to ageing → can we measure that?

Can we globally evaluate the performances of a person?



Measuring the way a task (e.g. postural) is done can be important to evaluate the capacity of the person to maintain it.

- > Until recently, use of statistics on the movments of the Center of Pressure (CoP) displacements
 - Provide an overall image of sway and of muscular strategies.
 - No insights on the control strategy or attentional demand.
- ► Non-Linear methods are successful tools for dynamical structure of CoP displacement analysis → RQA, DFA, Lyapunov exponent, etc.)
- > Entropy of interest for regularity of time series.
 - Sample entropy seems the most appropriate (corrects the bias of counting self-matches and less dependent on size) and applied to various time series (HRV, Gait, CoP displacement)
 - In double task paradigm → studies suggest that entropy reflects attention investiments (less attention, greater entropy)
 - Smaller entropy \rightarrow regularity \rightarrow repetitive patterns without possibility to adapt to new situations.

► To show attention investment, no double task but degradation or improvment of proprioception





2: MATERIALS AND METHOD

2.1 Measurement material and extracted features



Material:

- A force platform (Equi+, model PF01, Aix les Bains, France), consisted of an aluminum plate (80 cm each side) laying on three uni-axial load cells (0-50 daN)
- Acquisition of the signal at 64Hz, no filtering of the signal.

 $V_{CoP} = \sqrt{\frac{1}{N-1} \sum_{i=1}^{N-1} (\frac{RD_{i+1} - RD_i}{\delta t})^2}$ (in mm/s)

Extracted features:

- Measurement by the force platform are made on both Antero-posterior and Medial-Lateral plans Both time series are centered (0 mean)
- Resultant distance is computed as the distance from the center of the platform to each point of the posturogram. From this extraction of: $A_{CoP} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} RD_i^2} \text{ (in } mm)$
 - Root-mean-square of CoP displacement
 - Root-mean-square of CoP velocities
 - Sample Entropy of CoP



For sample entropy

- Distributions of points were normalized (centered and s.d. of 1).
- Parameters of computation of sample entropy (the tolerance of the standard deviation and the number of points of the window) were optimized using a grid search (m = 3, r = 5%).

Statistical Analysis

- > The means of the three trials for each experiment were used for statistical analysis
 - Kolmogorov-Smirnov test of equality of variance showed non-normality)
 - Two-tailed t-test with p = 0.05 used to perform the statistical analysis for each experiments





Two studies have been designed.

Participants:

Two experiments have 10 young men, all university students and without any known disorder related to cognitive or postural capabilities volunteered.

Task:

Eyes closed, stood barefoot on the force platform in a standardized position (feet abducted at 30°, heels separation 3 cm), arms hanging loosely by their sides.
 Asked to stand as still as possible.

► Experiment 1: task was executed in two support surfaces conditions (Firm and Foam). The force platform served as the Firm support surface. In Foam condition, a 2-cm thick foam surface, alters the quality and/or quantity of somatosensory information at the plantar sole and the ankle. → degradated condition

Experiment 2: the postural task was executed in two No-AFO (Ankle-Foot Orthosis) and AFO condition. In the AFO condition, one on each foot.





3: EXPERIMENTAL RESULTS

3.2 Results



► As expected:

- In experiment 1, changes in the floor \rightarrow Increase of both displacement and velocity, decrease of entropy
- In experiment 2, putting the orthosis \rightarrow decrease of both displacement and velocity, increase of entropy





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Depending on the modification of somatosensory perception, change in the strategy of postural handling.

Sample Entropy could be a good indication on the level of automaticity of the task.





Conclusions:

- Maintening quiet standing is automatic but depending on sensing condition or evolution of the person, could become challenging.
- Looking for easy-to-use assessment of attention investment is important for fall prevention for instance.
- Depending on the study, the results could diverge or be non-significant if the conditions were not enough controlled.
- In our results, improving the somatosensory sensations decreased the sample entropy → richer signal (more variety and less predictability) means also lower attentional demand (more automaticity).
- \triangleright Be careful, difficulty to interpret entropy results \rightarrow association with sway parameters.

Perspectives:

We worked also on a wavelet-based entropy, using synchro-squeezing to analyze transient signals.

Integration of these parameters into home-monitoring system to perform evaluation of the person and of a risk of fall?



