Cardiovascular and Cardiorespiratory Interactions – From Physiological Mechanisms to Clinical Applications
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Causal Discovery, Markov Chains, and the Degrees-of-Freedom Method

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joint work with Marcell Stippinger[1], Zsigmond Benkő[1], Dániel Fabó[2],
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We have time-series observations of two interacting systems. We investigate their separate and joint behavior. Taking into account their past states, can reveal their causal relationship.

The analysis can distinguish whether one system drives the other, the interaction is bidirectional, or whether their dependence is due to a common, possibly hidden, driver. In addition, investigation of their Markov properties can reveal whether one or both observed processes are subject to further separate hidden influences.

The lecture introduces causal discovery, Markov-chain analysis, and the degrees-of-freedom method as complementary tools for identifying these different causal structures from time-series data. [1, 2, 3]

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[2] Telcs, A., Kurbucz, M.T. and Jakovác, A., 2025. Unified causality analysis based on the degrees of freedom. *Physical Review E*, *112*(1), p.014204.

[3] Jakovác, A., Fabó, D., Erőss, L., Stippinger, M., Benkő, Z., Somogyvári, Z. and Telcs, A., 2026. Causality beyond the Reichenbach principle: the degrees-of-freedom method. *Scientific Reports*. doi:10.1063/5.0158923