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Non-monotonic complexity with increasing numbers of delays

We investigate transitions to simple dynamics in first-order nonlinear differential equations with multiple delays. Multiple delays can destabilize fixed points and promote high-dimensional chaos, but many delays can also induce stabilization onto simpler dynamics. We focus on this behaviour as a function of the number of delays. Dynamical complexity is shown to depend on the precise distribution of delays. A narrow spacing between individual delays favours chaotic behaviour, while a lower density of delays enables stable periodic or fixed point behaviour. During complexity decrease, the number of roots of the characteristic equation around the fixed point that have a positive real part decreases. These roots behave in fact in a similar manner to the Lyapunov exponents and the Kolmogorov-Sinai entropy for these multi-delay systems, and can thus serve as a proxy for those dynamical invariants. Our results rely on a novel method to estimate the Lyapunov spectrum of multi-delay nonlinear systems, as well as on permutation entropy computations. Surprisingly, complexity collapse upon adding more delays can occur abruptly through an inverse period-doubling sequence. Our results shed light on the dynamical effects of the transition from discrete to continuous delay distributions. We also discuss the implications of our results for reservoir computing.