Localized homological reorganization of brain functional scaffolds after LSD administration

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In this work we analyse the algebraic topological features of the functional brain networks of subjects before and after the subministration of LSD. Recently a number of techniques rooted in algebraic topology have been proposed as novel tools for data analysis and pattern recognition [1, 2]. The fundamentally new character of these tools, collectively referred to as TDA or topological data analysis, stems from abandoning the standard measures between data points (or nodes, in the case of networks) as the fundamental building block, and focusing on extracting and understanding the shape of data at the mesoscopic scale. These techniques have been used with success in biological and neurological contexts [3, 4, 5] and play a key role in understanding complex systems in a wide range of fields by extracting useful information from big datasets.

Here we do this by summarising the persistent homology information of the functional networks in a set of surrogate networks, called persistent homology scaffolds [3]: roughly speaking, persistent homology memorizes for how long brain functional cycles are active and the scaffolds compress this information effectively yielding a topological skeleton of the original network. Scaffolds have also been shown to carry meaningful and non-trivial information about functional connectivity both in normal [6] and altered brain states [3]. In this contribution, we show how topological information is able to detect subtle differences in the fMRI homological structure with and without drug. In particular, the scaffolds in the two conditions (drug-free vs LSD) display very similar global properties, e.g. weights distributions on the scaffolds, degree centrality distribution (Figure 1 (c) and (d)). However, a careful investigation of the scaffolds shows a significant difference in the localization of the topological features leading to a significantly different modulation of the weights of the edges common to both groups: common edges suffer a strong reduction in their persistence under the effects of LSD (see Figure 1 (a) and (b)), while the distributions of weights for edges belonging to a single group do not show significant differences. This suggests the existence of an underlying topological core that is only deformed by the drug. The obtained results are robust for analysis at both the subject and group level. Finally, we compare the results for LSD with previous results on another psychedelic drug, psilocybin [3], and show that two similar drugs produce starkly different topological alteration of the brains functional structure.

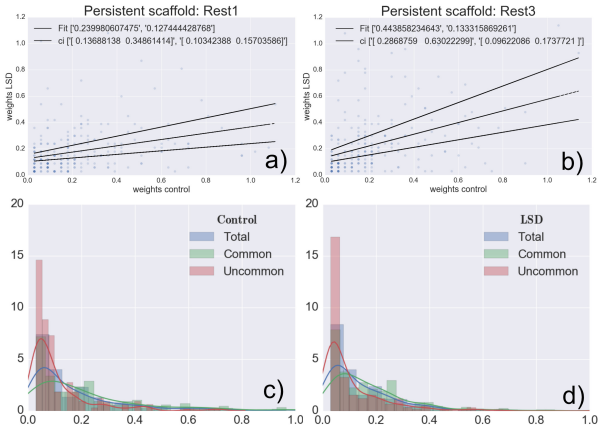

Figure 1: The comparison of common persistence scaffolds weights for control and LSD subjects shortly after the drug administration (a) and in a successive session (b) distinctly different linear slopes, highlighting a modulation in the topology (as exemplified by the fit) and a slow return to the placebo state. Notably, these patterns are not detectable by considering the edge weight distributions alone ((c) and (d), which display weight distribution from the persistence scaffolds for common and uncommon edges).

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