Machine learning in fMRI

Decoding

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Outline

1 Motivation
The decoding problem

The decoding problem I

- Typical functional imaging studies compare brain activity during different experimental conditions to discover what brain regions are activated by particular tasks.

The decoding problem II

- The classic application of MultiVariate Pattern Analysis (MVPA) to functional imaging data is for so-called

brain reading or ***decoding***

Using patterns of brain activity to perform a reverse inference and decide what subjects are looking at or thinking about [2].

Applications I

- This technique has grown in popularity, and has successfully been applied to a variety of paradigms, including discriminating between: [1]
  - object categories,
  - visually presented and attended stimuli,
  - remembered stimuli,
  - intention to engage in a task,
  - and deception.

Applications II

- In the domain of object/concept representation:
  - Three recent studies have shown that by training classifiers to represent meaningful aspects of the stimuli, one can decode from a large set of novel images, accurately reconstruct novel stimuli that subjects have never seen, and make quantitative predictions about what responses to novel stimuli should look like.

Applications III

By applying classifiers trained in one domain to stimuli in a different domain, we can test hypotheses regarding the functional overlap of neural circuitry.

Applications IV

- Knops et al. (2009) trained a classifier to discriminate between left and right saccades:
  - Based on posterior parietal activity during a spatial attention task.
  - The same classifier was used to decode addition or subtraction operations.
    - In order to test the hypothesis that mental arithmetic uses circuitry involved in spatial coding.
  - The classifier identified more addition operations as rightward saccades, compared to subtraction.
  - Indicating that mental arithmetic engages spatial coding circuitry in the parietal cortex.

Applications V

- Several groups have applied MVPA to detect neural representations related to behavioral variability.
  - Taking advantage of the fact that MVPA can be sensitive to information coded by different sub-populations within a specific region.

Applications VI

- Li et al. (2009) demonstrated that as subjects learn to categorize identical stimuli using different rules, patterns of neural activity in specific brain regions reflect the categorical decision, rather than the stimulus features.

Applications VII

- Raizada et al. (2009) have also shown that in individuals with differential ability to discriminate /ra/ and /la/ phonemes (e.g., native English and Japanese speakers), the amount to which a subject distinguishes between two stimuli behaviorally is related to the statistical separability of activity patterns in auditory cortex.
    - This approach may be useful for understanding behavioral differences in a wide range of paradigms, including understanding how behavioral impairments in children relate to differential stimulus coding in the brain.

Applications VIII

- Yoon et al. (2008) demonstrated that multivariate techniques may be more sensitive to differences between patients and controls by
  - Qualitatively comparing the performance of a neural-network classifier to a GLM-based analysis.
  - They trained a classifier to distinguish between categories of visually presented objects during a 1-back memory task.
  - Classification was more accurate in controls compared to patients; however, the GLM did not show any significant differences between the groups.
  - Note that in this study the classifier did not explicitly distinguish between patients and controls, but rather showed that spatial response patterns were less consistent in the patient group relative to controls.

Comments

- Task design is changing for new experiments with this approach.
- By interrogating the patterns of activity that classifiers rely on to make inferences, we can gain information about which voxels in the brain are the most informative.
- Decoding subjective experience can also contribute to our understanding of functional differences in brain disorders.

Summary

- Decoding: using patterns of brain activity to perform a reverse inference and decide what subjects are looking at or thinking about
- This new approach is changing fMRI experimental designs.
- Many applications have been presented.

References I

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