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A nonparametric Bayesian approach to adaptive sampling of psychometric functions

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Psychometric functions express the relation between stimuli parameters and responses of subjects. As these functions have to be estimated from experimental data one encounters several difficulties:

1. Standard estimation techniques like the maximum likelihood method (see [1,2]) result in large biases and it is usually hard to give precise statements about the confidence in the estimates.

2. It is common in the neurosciences that the number of experimental trials is strongly restricted: Data acquisition might be expensive, tested animals or humans might get tired or might learn too quickly, etc.

3. Usually psychometric functions are modeled by function families having only a small number of parameters [1,2], thus parametric models might imply too strong assumptions about the psychometric function courses.

As an example for the third point, we refer to an ongoing research debate about the time course for early visual processing. For the detection and discrimination impairment of a stimulus by a closely followed second stimulus, two competing models exist (U-shaped vs. monotonically increasing, see [3]) that had been related to special types of experiments each. Recent experimental results, however, demonstrate severe violations of these experimental assumptions [4,5], but the question whether any of these two models is appropriate at all remains open. A suitable nonparametric inference might help to find better descriptions of the experimental data and finally to develop new models with only a few parameters.

To overcome the problems above, we consider some recent ideas:

1. Making use of Bayesian techniques for estimating psychometric functions gives much more reliable estimates together with trustworthy confidences [6].

2. Adopting the nonparametric approach of multi binning for linking stimuli parameters and their responses for estimating peristimulus time histograms of spike trains [7].

3. Adaptive sampling with respect to maximize the information gain in each sample step should help to exploit a limited number of experimental trials [8].

By incorporating those ideas, we propose a universal estimation technique that will help to detect novel features in psychometric functions when there is only little prior knowledge about the underlying mechanisms.

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