Multi-Step Look-Ahead Adaptive Designs for the Estimation of Sensory Thresholds

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Abstract

The estimation of sensory thresholds is an important part of the psychophysics field. The point at which a physical stimulus becomes detectable can vary from trial to trial within as well as between subjects. Often the probability of detection is modelled over a range of stimulus intensities using an assumed psychometric curve which has the threshold as a parameter. To estimate the threshold with a reasonable accuracy often requires careful placement of the stimulus levels when the total number of trials are limited. There have been a number of design schemes proposed over the years to find the optimum placement strategy to minimise a given loss function. Some of the most successful have been Bayesian adaptive designs which select the next signal intensity based on prior knowledge and the responses observed up until that point. A critical step in the adaptive designs is the choice of threshold estimator and error term, also known as the loss function, to be minimised by the design scheme. A sub-class of these look-ahead a short number of trials to calculate the expected loss function given the current posterior distribution. However sometimes it is not possible to adjust the signal after every test. Olfactory sensory threshold tests, for example, can require a large setup time. In this situation a number of sensory tests may be grouped into sessions, with any design alterations occurring between these. However this would require a look-ahead design with a number of steps equal to the number of samples in a session.

Most of the look-ahead designs have been restricted to one or two steps due to the little performance increase gained by increasing them and the computational limitations at the time they were suggested. The first point is not relevant to situations where the step size must be larger, and the second point may be less true today due to advances in computer power. This investigation demonstrates that it is possible to implement multi-step look-ahead adaptive designs in a computationally efficient manner for sessions up to sizes of twelve samples. Based on Monte-Carlo simulations, these multi-step look-ahead designs also provide encouraging results in terms of performance in minimising a number of loss functions.

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