Active Learning for a Number-Line Task with Two Design Variables

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Abstract

The number-line task is a widely used task in diverse fields of study. In the task, a given number that varies every trial is estimated on a continuum flanked with 0 and an upper-bound number. An upper-bound of a number-line is often arbitrarily selected by researchers, although this design variable has been shown to affect the non-linearity in estimates. Examining estimates of varying given numbers (design variable 1) with varying upper-bound numbers (design variable 2) can be costly because adding a new design dimension into a number-line task could drastically increase the number of trials required for examining the underlying representation of number. The present study aims to conduct a number-line task with the given number and the upper-bound being the design variables. A design optimization algorithm, Gaussian Process Active Learning (GPAL), made this new paradigm feasible without increasing the number of trials, by presenting only the most informative combinations of the design variables every trial. Our experimental data showed that the non-linearity of the number-line estimates increases with the upper-bound of the number line. The degree of non-linearity could predict a math skill (i.e., addition proficiency), but only when the upper-bound was relatively large. The observed range-dependency of the number-line estimates would not be fully explored without systematically manipulating the upper-bound as an additional design variable. As in the present number-line task, GPAL would be a useful tool for the research problems that require multidimensional design experiments to be solved.