Estimation of Probability
in nonstationary environments

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Abstract

There is little research on how people estimate varying probabilities, aside from inferences made from decision-making experiments. Previous studies have approached the question by analyzing discrete variations in hidden probability parameters and by asking the subjects directly for their perceived estimations. The present work examines the participants' ability to trace changes in the hidden probability parameter of a Bernoulli process, where the parameter changed continuously and where the initial varying conditions were altered without alerting the subjects. This work's results show that participants could successfully follow continuous changes in the true probability parameter.

Introduction

It is essential to learn about the psychophysics of subjective probability assessment. However, experiments to directly study the probability estimation process are scarce. In 1984, Estes looked into how people perceived a continuous pattern of changes in probability and how they reacted to a shift into a different pattern of probability fluctuations. Another example is Gallistel (2014), who conducted an experiment to analyze people's trial-by-trial estimation of discrete changes in a hidden probability parameter.

The purpose of this work was to examine to what extent participants were sensitive to a varying probability environment. In particular, this study intended to explore if people were able to follow continuous changes in the value of a hidden probability parameter and if there was a delay between the change in the parameter's value and the subjects' estimate adjustment. Another objective was to see if there was an effect over the participants' estimate upon transitioning into a different pattern of probability changes.

Method

40 students faced a Bernoulli process and could observe either a red or a green marble on a given trial. They were asked to estimate the hidden probability of obtaining a green outcome and to report if they detected a change in the aforesaid value. The probability could vary according to a sine wave (SW), a mirrored sine wave (MSW) or could be fixed at 0.6 (FP). Participants were divided into 4 groups; each group was exposed to 2 of the previous conditions:

- Group 1 (SW-FP)
- Group 2 (SW-MSW)
- Group 3 (FP-SW)
- Group 4 (MSW-SW)

Results

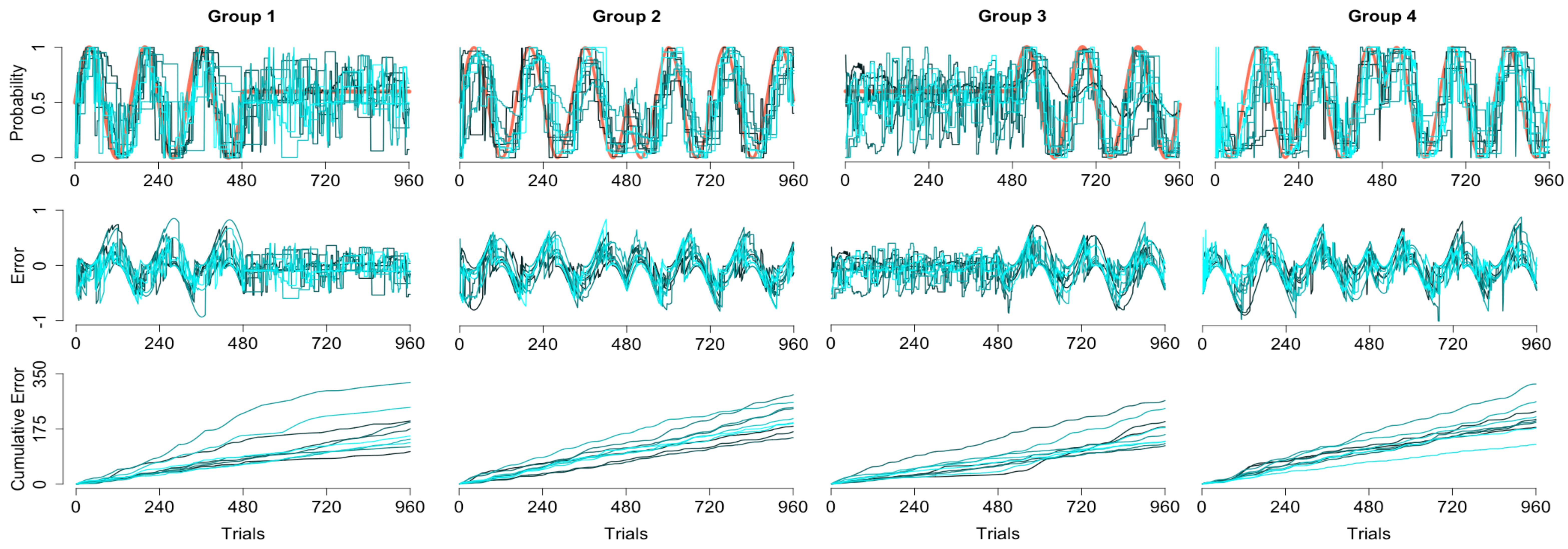

Figure 1. The columns represent each experimental group's performance. The first row shows every participant's (each respresented by a different shade of blue) trial-by-trial tracking of the true probability (orange). The second row shows the error of the subjects' response respect to the true probability value on every trial. The third row shows the cumulative sum of the error displayed on the second row.

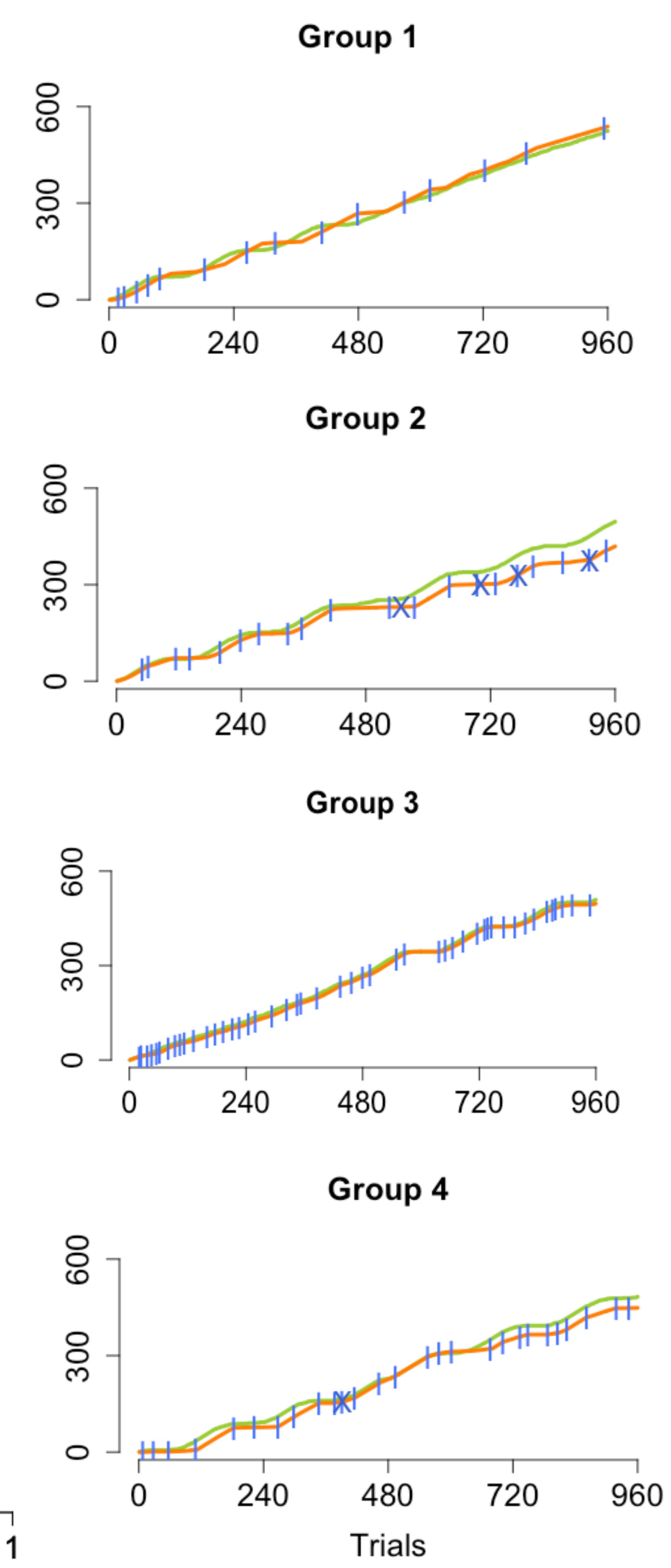

Figure 5. The cumulative sum of the estimate of 1 representative participant per group (orange) and the cumulative sum of the green outcomes observed during the experiment (green). The blue vertical lines represent the moment when each participant reported a change in the probability parameter value; the blue crosses show when they regreted their previous report of a change in this value.

Lag Values

Participant	Group 1 (SW)	Group 2 (SW)	Group 2 (MSW)	Group 3 (SW)	Group 4 (MSW)	Group 4 (SW)
1	12	4	5	44	16	8
2	27	11	14	20	16	20
3	5	12	12	10	18	18
4	11	21	25	18	17	18
5	16	26	34	6	20	12
6	50	19	29	10	33	35
7	3	39	15	29	30	22
8	26	17	22	7	23	14
9	3	17	15	31	6	2
10	12	21	13	10	19	13

Figure 2. Lag value (in trials) that minimizes the error for each participant. Including a delay does not aid in minimizing the error for the FP condition, so those columns were omitted.

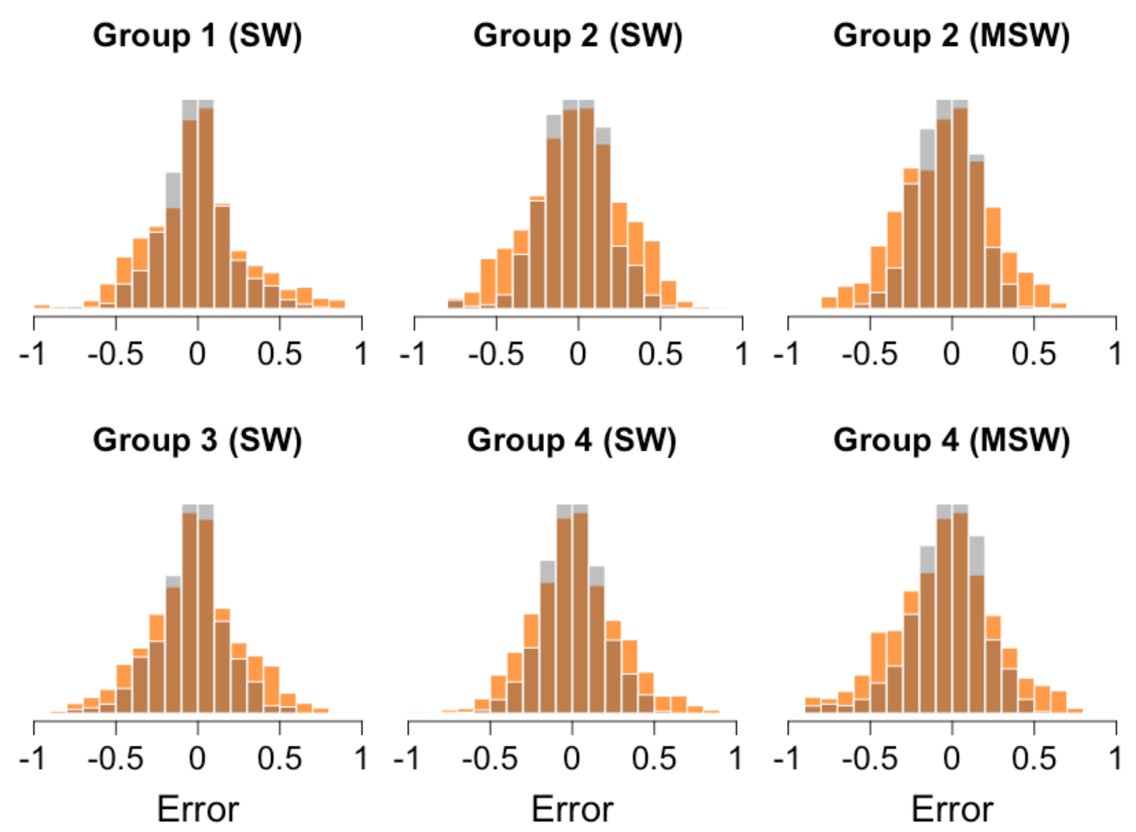

Figure 3. The error distribution for the original data (orange) and the error distribution for the adjusted data, when taking away the lag between the particpants' estimates and the observed stimulus (gray).

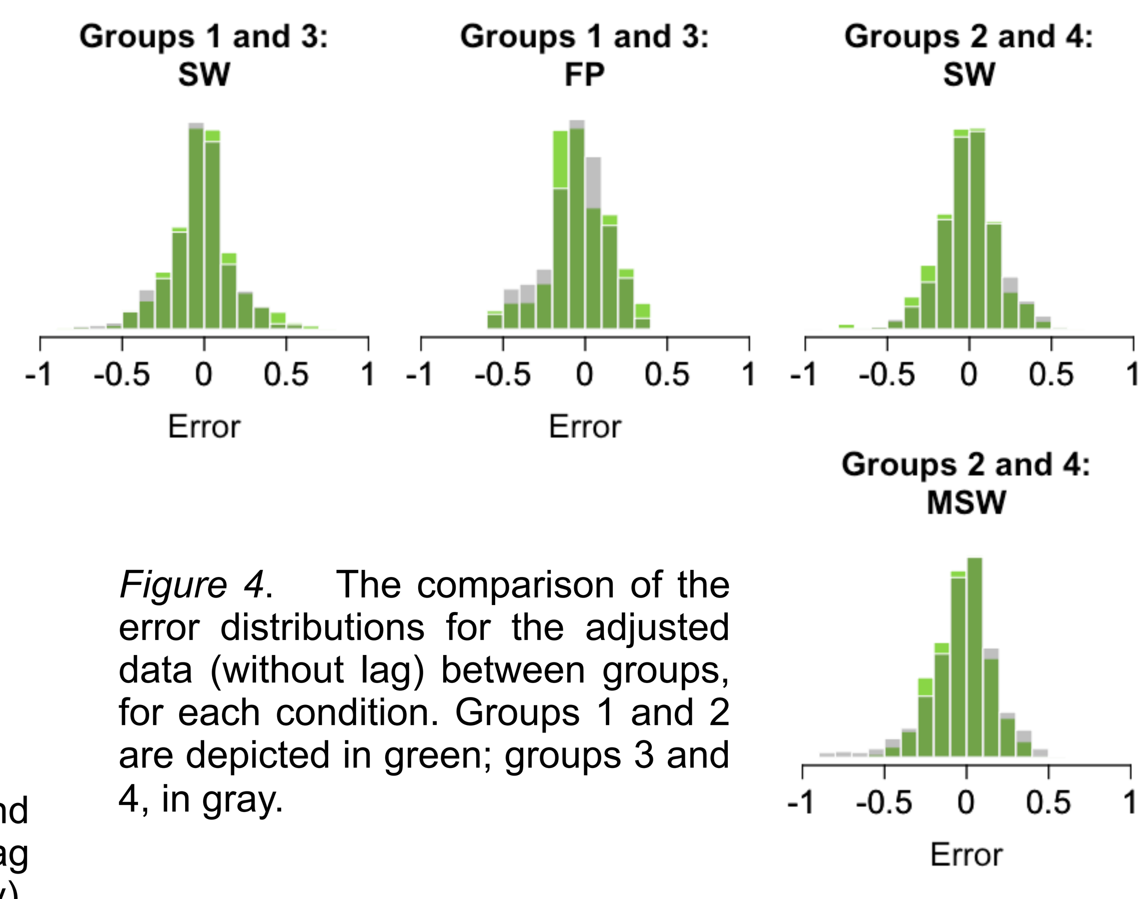

Figure 4. The comparison of the error distributions for the adjusted data (without lag) between groups, for each condition. Groups 1 and 2 are depicted in green; groups 3 and 4, in gray.

Discussion

This work shows that participants are able to closely follow continuous changes in probability. Subjects are better at estimating continuously changing probability values than at identifying a fixed probability. The order of presentation does not appear to have a distinct effect over the participants' estimates in each condition. There is a lag between the observed stimulus and the subjects' adjustment of their estimates; it explains part of the error during the task.

References

Estes, W.K. (1984). Global and local control of choice behavior by cyclically varying outcome probabilities. *Journal of Experimental Psychology: Learning, Memory, and Cognition.* 10, 258 – 270 p.p.

Gallistel, C.R., Liu, Y., Krishan, M., Miller, R. (2014). The Perception of Probability. *Psychological Review.* Vol. 121, No. 1, 96 – 123 p.p.

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