Testing Models of Deferred Decision Making

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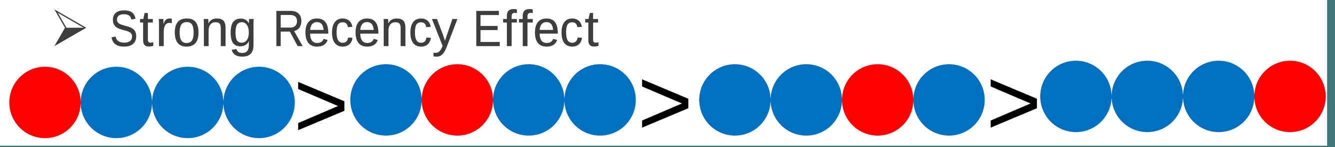
Introduction

How do people know when to defer a decision and collect more information, or when to stop sampling and make a final choice? This is a problem faced by physicians diagnosing an illness, consumers researching a purchase, and commanders taking military action. We conducted a study in which participants purchased up to twenty independent observations about two mutually exclusive medical conditions before making a final diagnosis. Their goal was to make accurate choices, while minimizing sampling costs. We tested several models and found strong support for the Time-Variant Sequential Sampling Model[5] over the Error Cost Stopping Rule[4].

Previous Research

- Several studies challenge the constant threshold assumption, instead showing that less evidence is needed over time
- Sanders & Ter Linden (1967)[1] and Viviani (1979)[2] found that the likelihood of terminating after a sequence of strong evidence was greater when preceded by non-diagnostic sequence
- Pitz, Reinhold, & Geller (1969)[3] found that late in a sequence of tests participants often terminated when the number of positive and negative tests was equal
- Busemeyer & Rappoport (1988)[4]
  - Terminating after non-diagnostic subsequence
  - Terminate contrary to final sample
  - Strong Recency Effect



Research Questions

- How much testing will people pay for before making a diagnosis?
- Cognitive Models best describe the deferred decision making process?

Cover Story

- Disease outbreak in a large city; flu-like symptoms
- Each patient is infected with one of two viruses
- Blood tests can be used to identify with virus is present
- Test error occur **40%** of the time!
- Maximum of 20 tests per patient

Experimental Method & Design

- 43 participants each diagnosed 72 patients
- Payoffs
  - Initial endowment of $10
  - + $0.65 for correct diagnosis
  - - $1 for incorrect diagnosis
- Test Cost Conditions
  - Constant: $0.05/test
  - Increasing: $0.01, $0.02, $0.03...

References

[1] Sanders, A. F., & Ter Linden, W. (1967). Decision making during paced arrival of probabilistic information. *Acta Psychologica, 21*, 170-177.

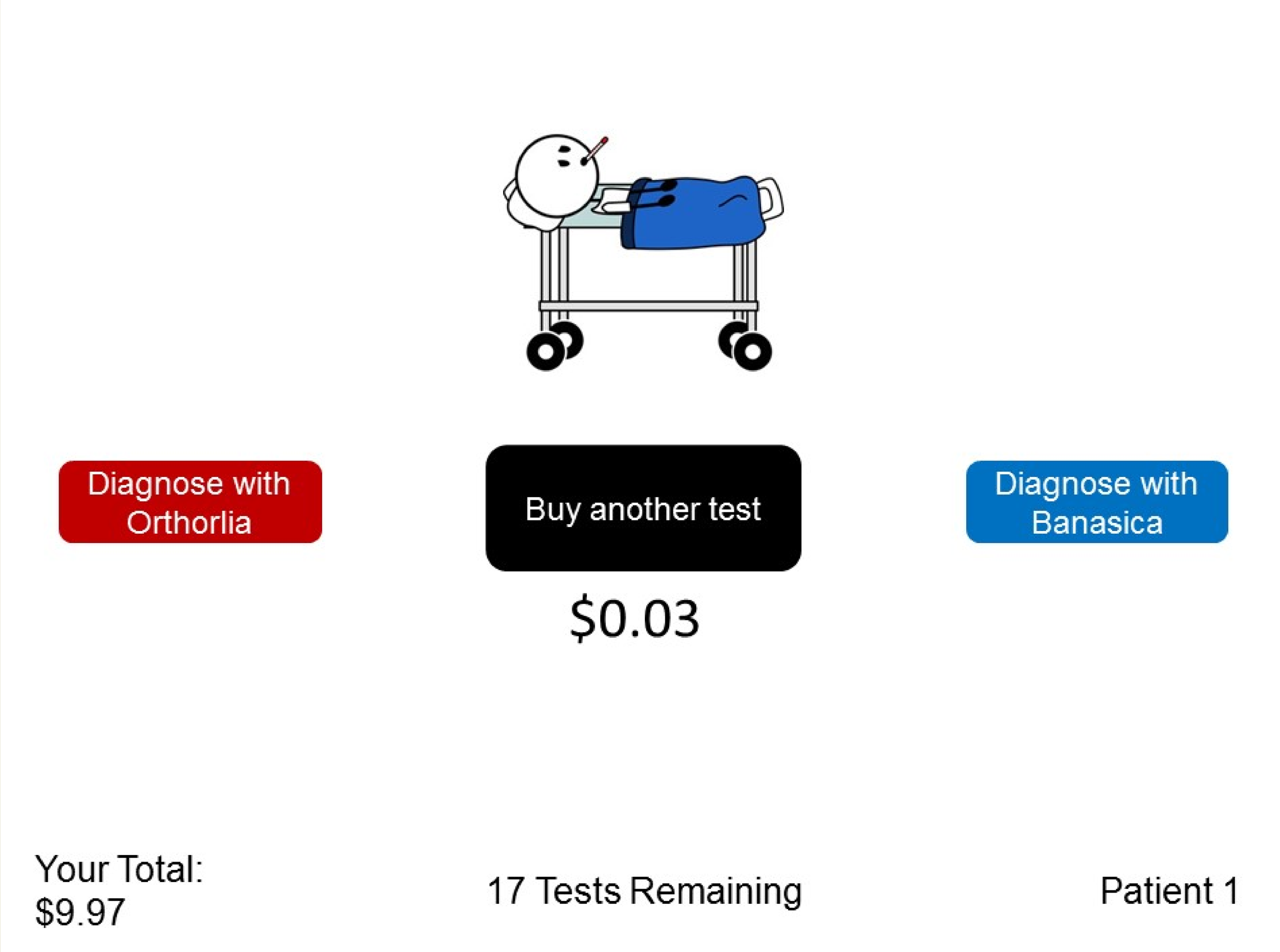
[2] Viviani, P. (1979). Choice reaction times for temporal numerosity. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 157-167.

[3] Pitz, G. F., Reinhold, H., & Geller, E. S. (1969). Strategies of information seeking in deferred decision making. *Organizational Behavior and Human Performance, 4*(1), 1-19.

[4] Busemeyer, J. R., & Rapoport, A. (1988). Psychological models of deferred decision making. *Journal of Mathematical Psychology, 32*(2), 91-134.

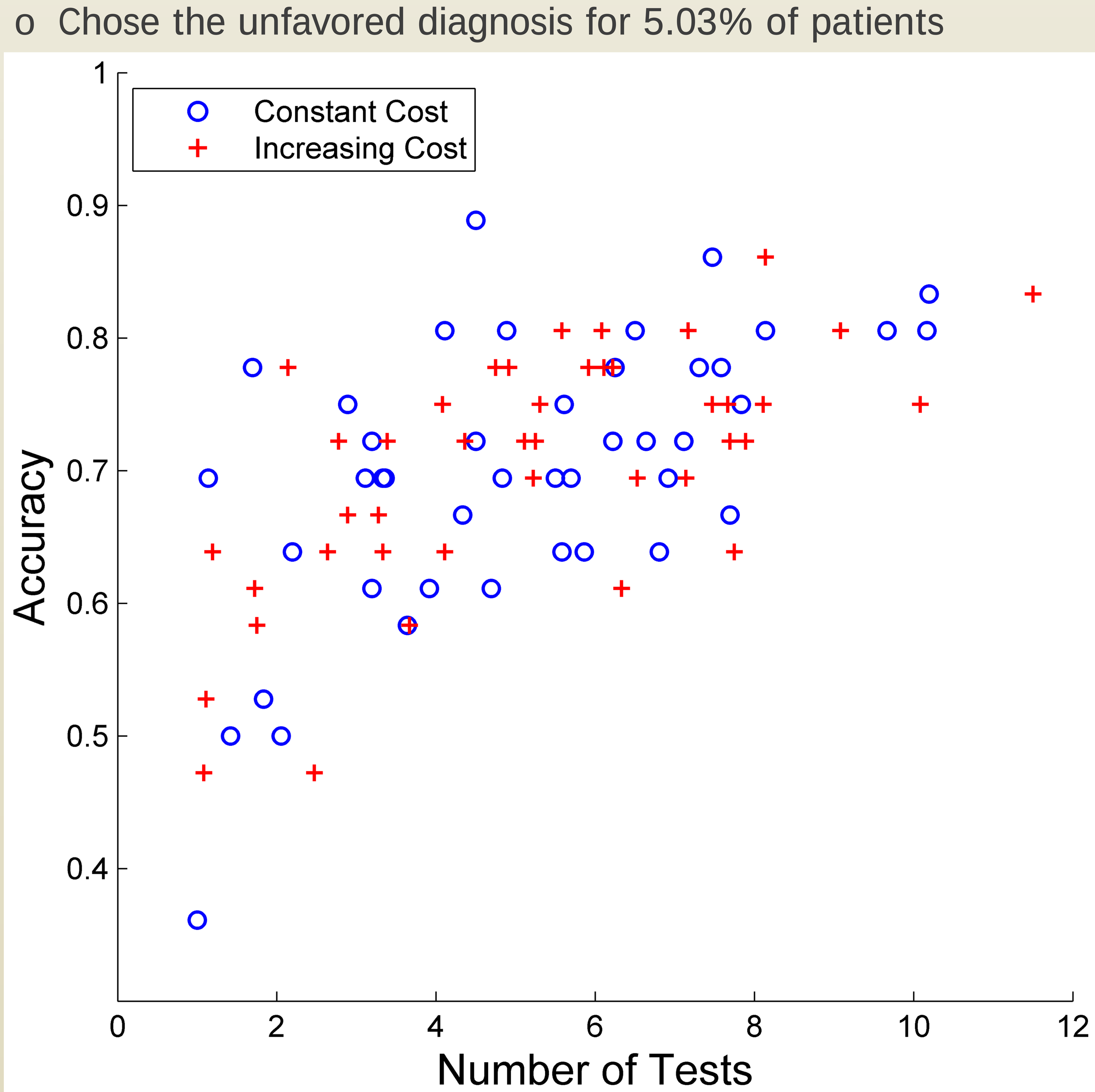
[5] Gluth, S., Rieskamp, J., & Büchel, C. (2013). Deciding not to decide: Computational and neural evidence for hidden behavior in sequential choice. *PLoS computational biology, 9*(10).

Medical Diagnosis Experiment



Results

- Purchased 5.179 tests per patient (StdErr = .37)
  - No difference across cost conditions
- Terminated with an average difference of 2.10 test results (StdErr = .09)
- Mean Accuracy: 0.70 (StdErr = .01)
- Terminated with equal evidence for each diagnosis for 4.84% of patients
- Chose the unfavored diagnosis for 5.03% of patients



Simple Models

- **Baseline Model** (2 versions)
  - Uses each individual's frequency distribution to calculate P(terminate | test #)
- **Constant Threshold Model**
  - Threshold (# of tests) is a free parameter
  - P(error) is a free parameter

Error Cost Stopping Rule

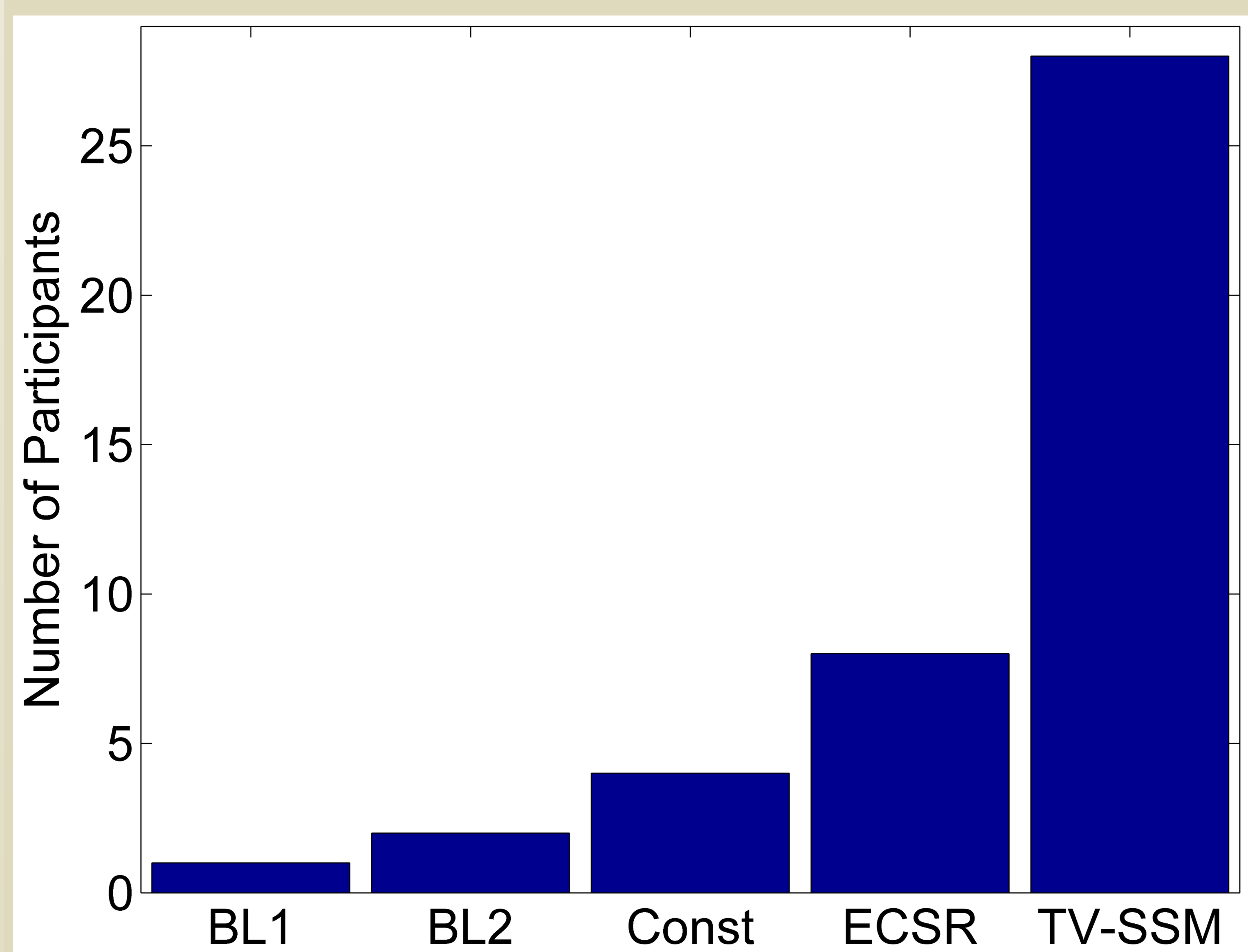
- Calculate the expected **error cost** and terminate when the cost of the next sample exceeds the **E(EC)** for one diagnosis
- E(EC Choose A) = P(B|evidence)*(R-P)
- Test Cost = subjective waiting cost + objective price
- Quantitative predictions calculated from stochastic version
  - P(terminate) = logistic [sample cost – min(E(EC))]
  - Final choice = logistic function of log-odds ratio
- Free Parameters (3)
  - Termination Sensitivity
  - Choice Sensitivity
  - Impatience Rate

Time-Variant Sequential Sampling Model

- 3-alternative accumulator model w/ collapsing thresholds
- All three choice alternatives explicitly represented
- Evidence accumulates continuously at constant rates
  - Alternative A & B
    - Drift rates are function of Expected Value (plus noise)
    - Threshold decreases over samples at constant rate
  - Sample Alternative
    - Drift rate inversely proportional to sample cost
- Decision made when one accumulator exceeds its threshold
- If A/B threshold < 0, choose disease favored by evidence
- Free Parameters (4)
  - θ_{AB}, θ_{sample}, A/B collapse rate, std(noise)

Model Comparison Method

- Fit to each individual using maximum likelihood
- Control for model complexity using BIC
- Create stochastic version of rule-based models to allow quantitative comparison



Conclusions

- More evidence against constant threshold
- Large individual differences
- Most individuals best fit by TV-SSM
  - Begin independently accumulating evidence in favor of each alternative
  - Quickly transition to simple choice rule
- Some individuals best fit by ECSR
  - Pessimistically focus on error avoidance, rather than maximization
  - Quickly terminate when impatience become large