Evidence Accumulation in a Complex Visual Domain: Applying the Linear Ballistic Accumulator to Fingerprint Discrimination

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ABSTRACT

Evidence accumulation models have been used to describe the cognitive processes underlying choice task performance across a number of domains. This class of models have generally been applied to basic perceptual stimuli (e.g., motion detection). Recent evidence suggests that these models can be used to account for complex, applied tasks (Palada et al., 2018); however, these studies use controlled tasks which were far removed from their inspiration in the field. In this experiment, we ask whether an evidence accumulation model, specifically the linear ballistic accumulator (LBA; Brown & Heathcote, 2008), can account for performance in a perceptual task using naturalistic stimuli: A fingerprint discrimination task. We found that the model was able to accurately describe performance and provided a coherent account of fingerprint discrimination.

INTRODUCTION

- Signal detection theory is the predominant framework used to understand perceptual discrimination of fingerprints.
- However, signal detection theory is a static model which cannot account for the temporal dynamics of the decision process. Indeed, response times and accuracy often have complex interacions.
- In signal detection theory, decreases in accuracy are usually interpretated as an increase in discriminability. However, this pattern of results may also result from increases in the amount of evidence required to make a decision (i.e., threshold or response caution).
- Evidence accumulation models, such as the LBA model can account for both accuracy and response times.
- However, it is unclear whether the LBA can be used to model complex decisions using stimuli with contextual factors which resemble those in the field.
- We apply the LBA to fingerprint discrimination performance to gain insight into the cognitive processes underyling this complex perceptual judgement.

METHOD

- Seventy students completed a fingerprint discrimination task (Figure 1).
- Ninety-six fingerprint pairs were sourced from the Forensic Informatics Biometric Repository (Thompson, Tangen & McCarthy, 2013).
- The set of prints were duplicated to create 192 fingerprint pairs with an equal number of matching and non-matching prints.
- We manipulated noise (no noise vs noise) and emphasis type (speed: "speed up" prompt for RTs > 5s vs. accuracy: "slow down" promtp for RTs < 5s).
- The 192 fingerprint pairs were equally split into the 2 x 2 cells.

Within Subjects:
Noise (no noise vs. 20% speckle) x Emphasis type (speed vs. accuracy)

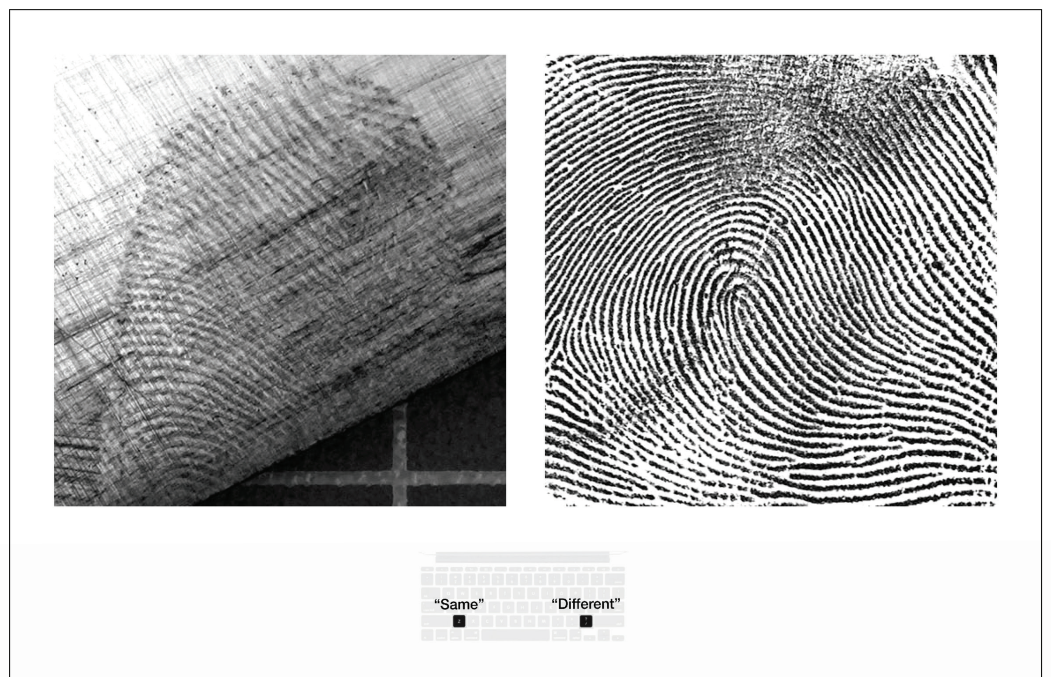

Figure 1. A single trial of the fingerprint discrimination task. In this case, matching prints are presented without noise.

RESULTS

OBSERVED BEHAVIOURS

Response Times:

Faster under speed emaphasis than accuracy emphasis.

Accuracy:

Poorer for prints presented with noise compared to no noise.
Improved under accuracy emphasis, though only for non-matches.

LBA MODEL PARAMETER ESTIMATES

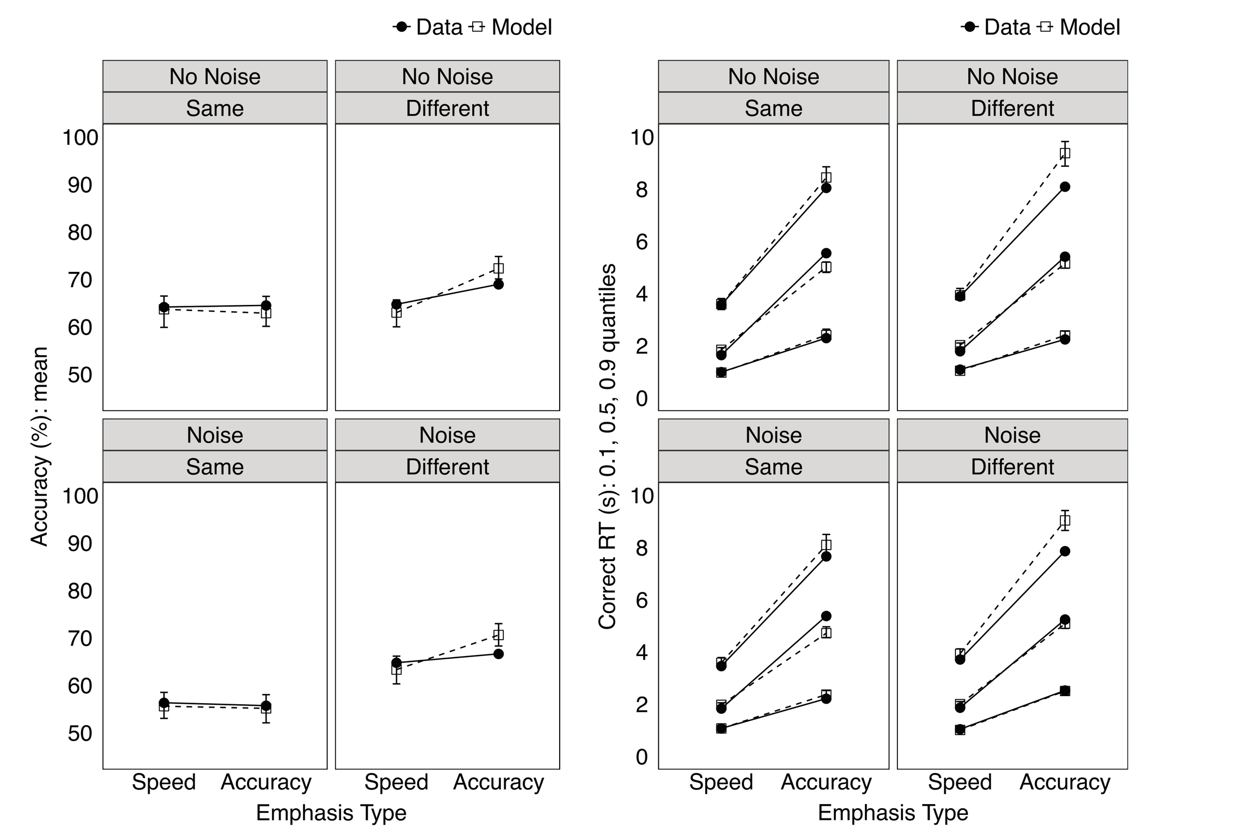

Figure 2. The LBA provided good fit to accuracy (left) and correct mean reasponse times (right).
The RT graph shows .1, .5, and .9 quantiles.
Black dots refer to observed performance. White squares refer to posterior prediction with 95% credible intervals.

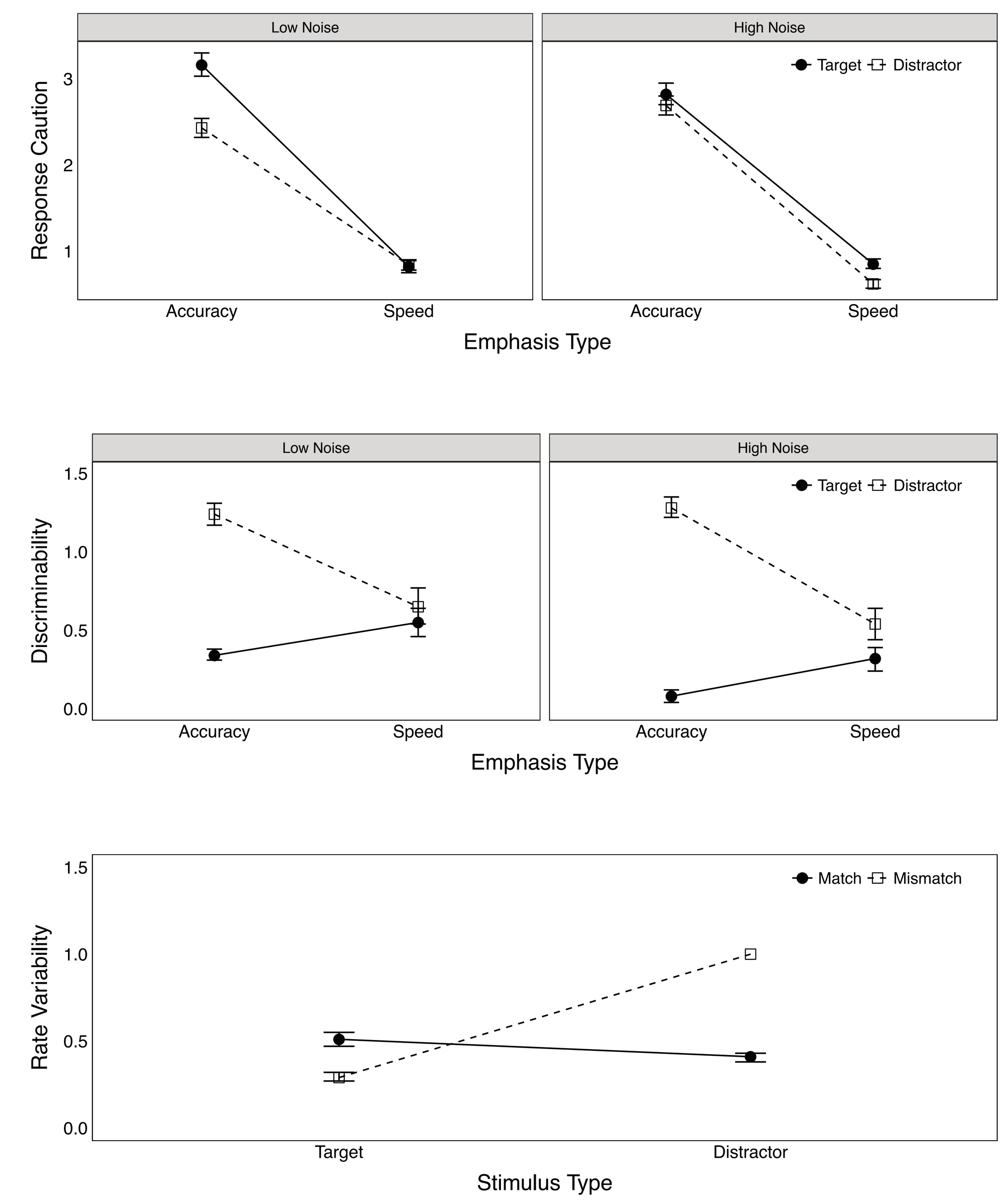

Figure 3. The effects of noise, emphasis and stimulus type on response caution (top) and discriminability (middle). The effects of stimlus type and the accumulator match factor on the variability of rate of evidence accumulation (bottom). Error bars show 95% Bayesian credible intervals.

LBA DECISION-MAKING MODEL

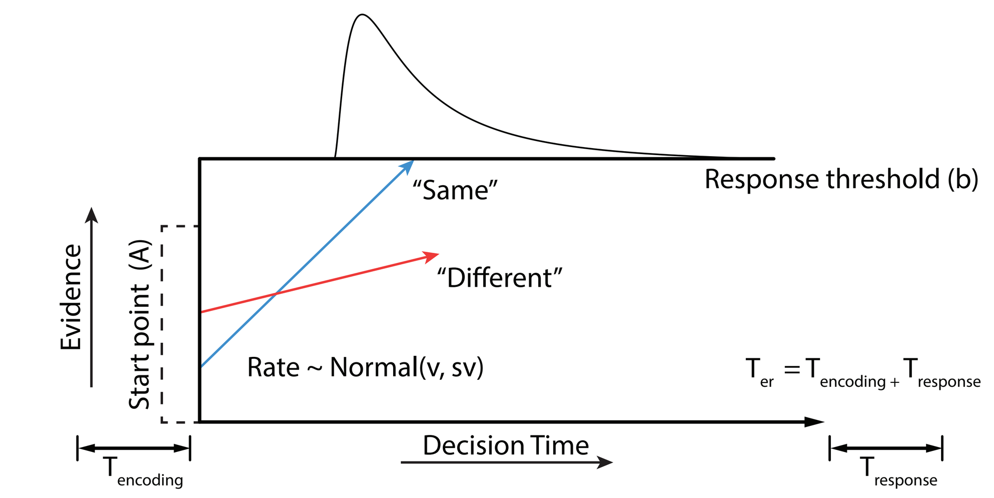

Figure 4. The LBA Model (Brown & Heathcote, 2004) architecture and parameters.

DISCUSSION

- Emphasis type (speed vs. accuracy) influenced response caution (i.e., the quantity of evidence required to reach a decision). Specifically, participants reduced their response caution under speed emphasis compared to under accuracy emphasis to accelerate their decisions.
- Participants adopted a "non-match" response bias. This only occured under accuracy emphasis and no noise; we suspect that participants were not willing to adopt this bias in other conditions as it would exacerbate the poorer performance for matching prints.
- In line with recent studies (Rae et al., 2014), emphasis type also influenced discriminability. For non-matching prints, discriminability improved under accuracy compared to speed. On the other hand, for matching prints, discriminability worsened under accuracy compared to speed. We suspect that this latter effect was due to participants having poor knowledge about diagnostic information for discriminating matching prints.
- Noise influenced discriminability. Discriminability for matching prints worsened with noise, but this did not occur for non-matching prints. The noise effect may have been sufficiently strong to obscure similarities among matches, but not strong enough to obsecure non-matching prints.

CONCLUSION

- The LBA provided an acccurate description of choice and response times in the fingerprint discrimination task using naturalistic stimuli.
- The modeling suggests that the features of the stimuli have significant implications on decision-making processes.
- We continue to provide evidence that evidence accumulation models can provide meaningful insight into applied decision-making.

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