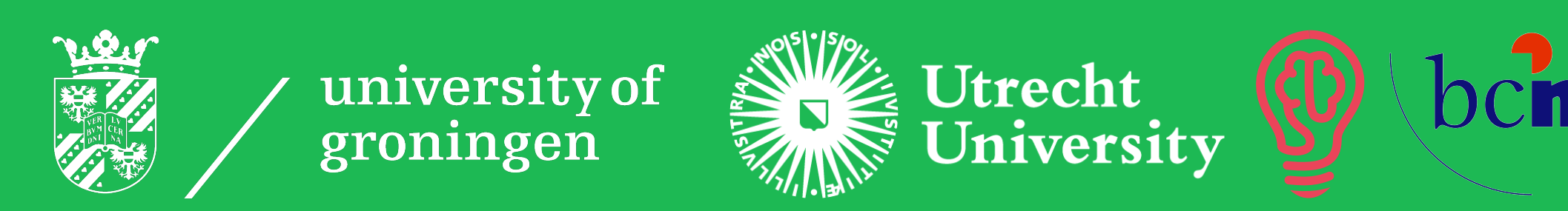


Capturing Behavioural Dynamics in a Cognitive Model of Memory Retrieval

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Key points

- The parameters governing our behaviour are in constant flux. Capturing such dynamics in cognitive models is challenging.
- A mapping between ACT-R's model of declarative memory and the linear ballistic accumulator (LBA) enables efficient estimation of memory parameters from data.
- Resulting parameter estimates provide a **cognitively meaningful explanation for observed differences** in memory retrieval over time and between individuals.

LBA maps onto ACT-R memory parameters

The ACT-R cognitive architecture (Anderson, 2007) represents each item in memory as a **chunk with activation** μ_i . The duration of a retrieval depends on activation, a latency factor \bar{F} , and the non-retrieval time t_{er} . Across trials:

$$\mathbb{E}(RT_i) = \bar{F} * e^{-\mu_i} + t_{er} = \frac{\bar{F}}{e^{\mu_i}} + t_{er}$$

The LBA (Brown & Heathcote, 2008) models a **competition of evidence accumulators** in which the winner determines the RT and choice. For each response option i , **evidence accumulates until it reaches a decision boundary d** , from a start point $k_j \sim U(0, A)$ at a drift rate $v_{ij} \sim N(v_i, s_i)$. A non-decision time t_0 captures stimulus perception and response execution. Across trials:

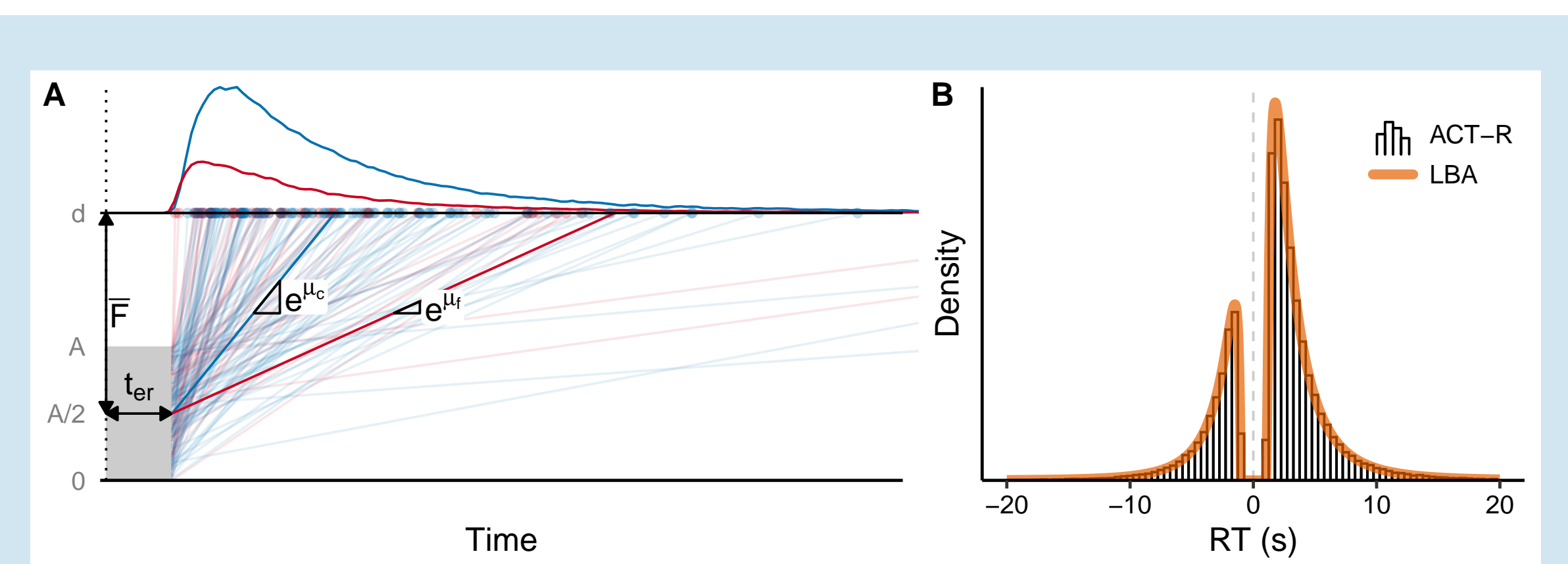
$$\mathbb{E}(RT_i) = \frac{d - A/2}{v_i} + t_0$$

Mapping

Latency factor $\bar{F} = d - A/2$

Activation $\mu_i = \ln(v_i)$

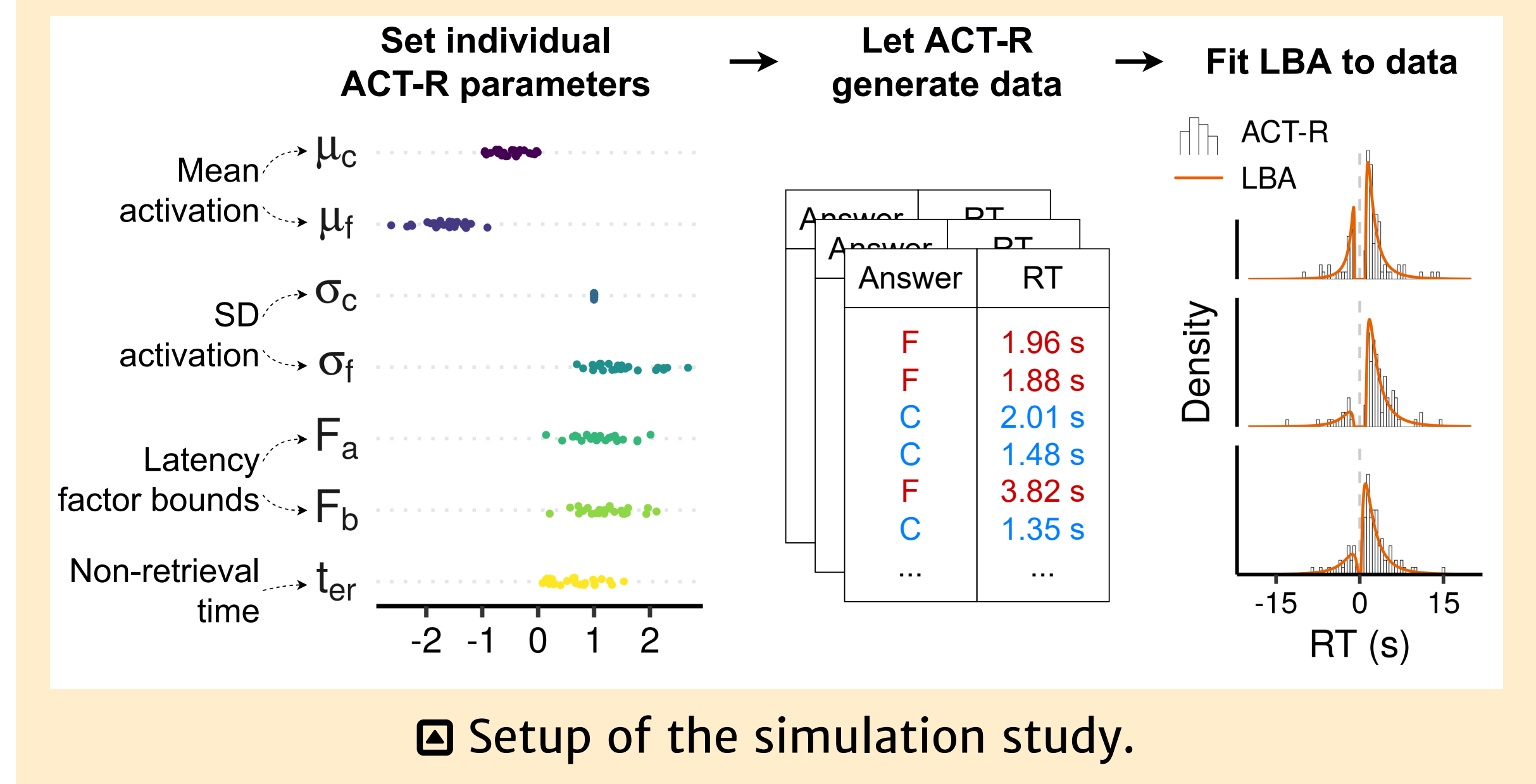
Non-retrieval time $t_{er} = t_0$



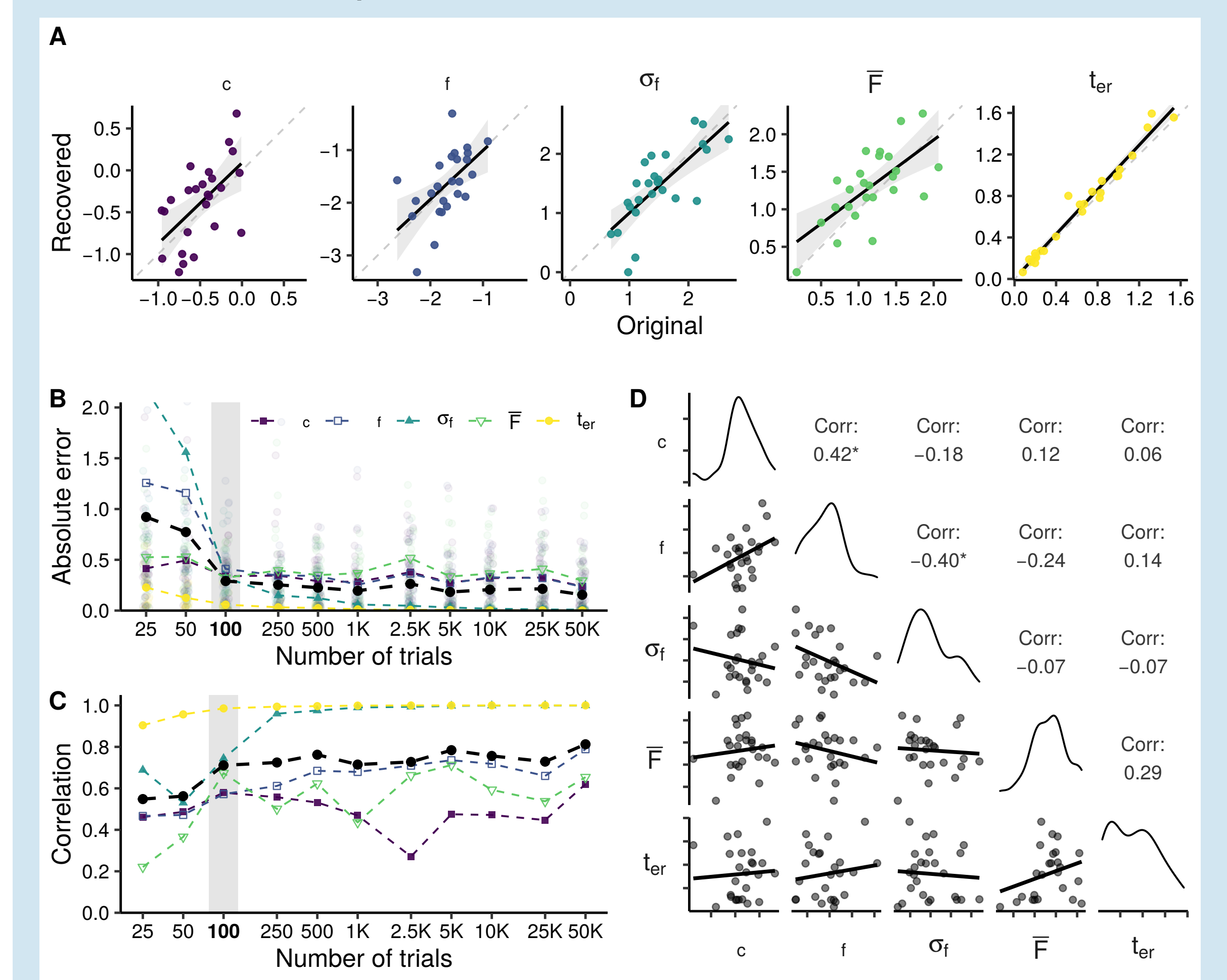
▣ Casting ACT-R memory retrieval as a linear ballistic accumulator. **A:** ACT-R retrieval with two competing chunks visualised as an LBA, with marginal RT distributions shown at the top. **B:** RT distributions of an ACT-R model (histogram) and the equivalent LBA model (orange curve). Error responses are shown as negative RTs.

Simulation: parameter recovery

Can the LBA **recover ACT-R parameters** from a typical sample? And does parameter recovery work **regardless of specific parameter values**?

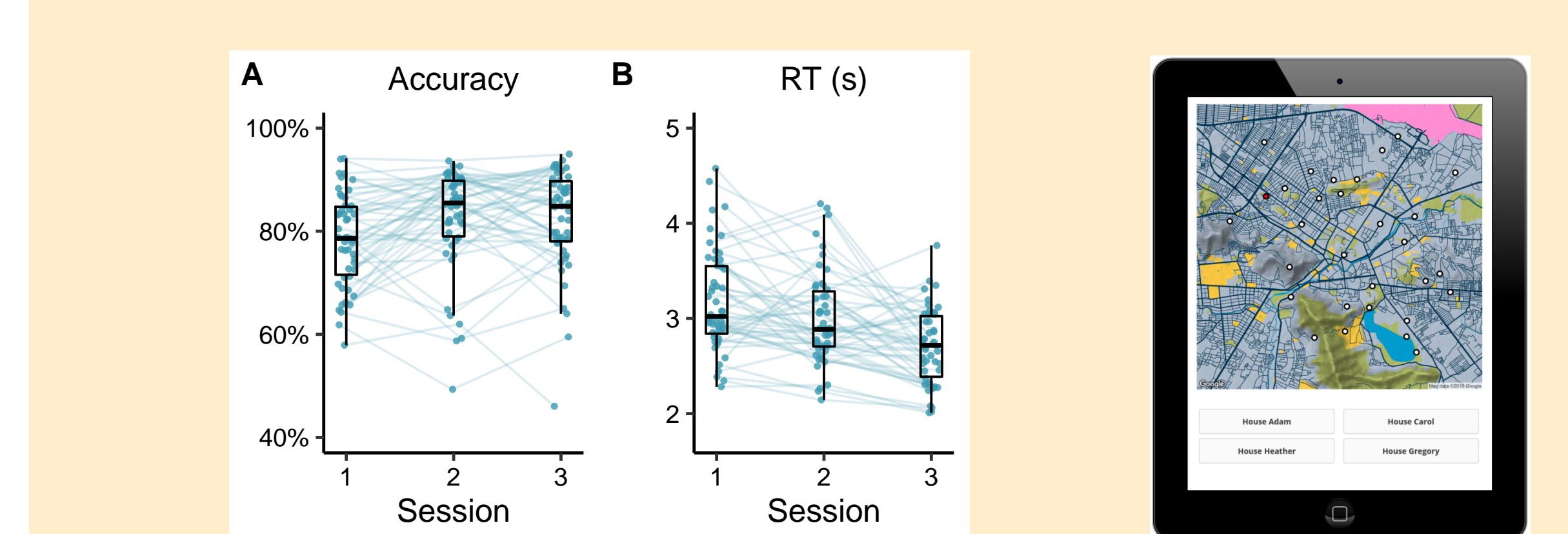


Yes, parameter recovery works. Performance improves with more data. Some parameters are easier to recover than others.

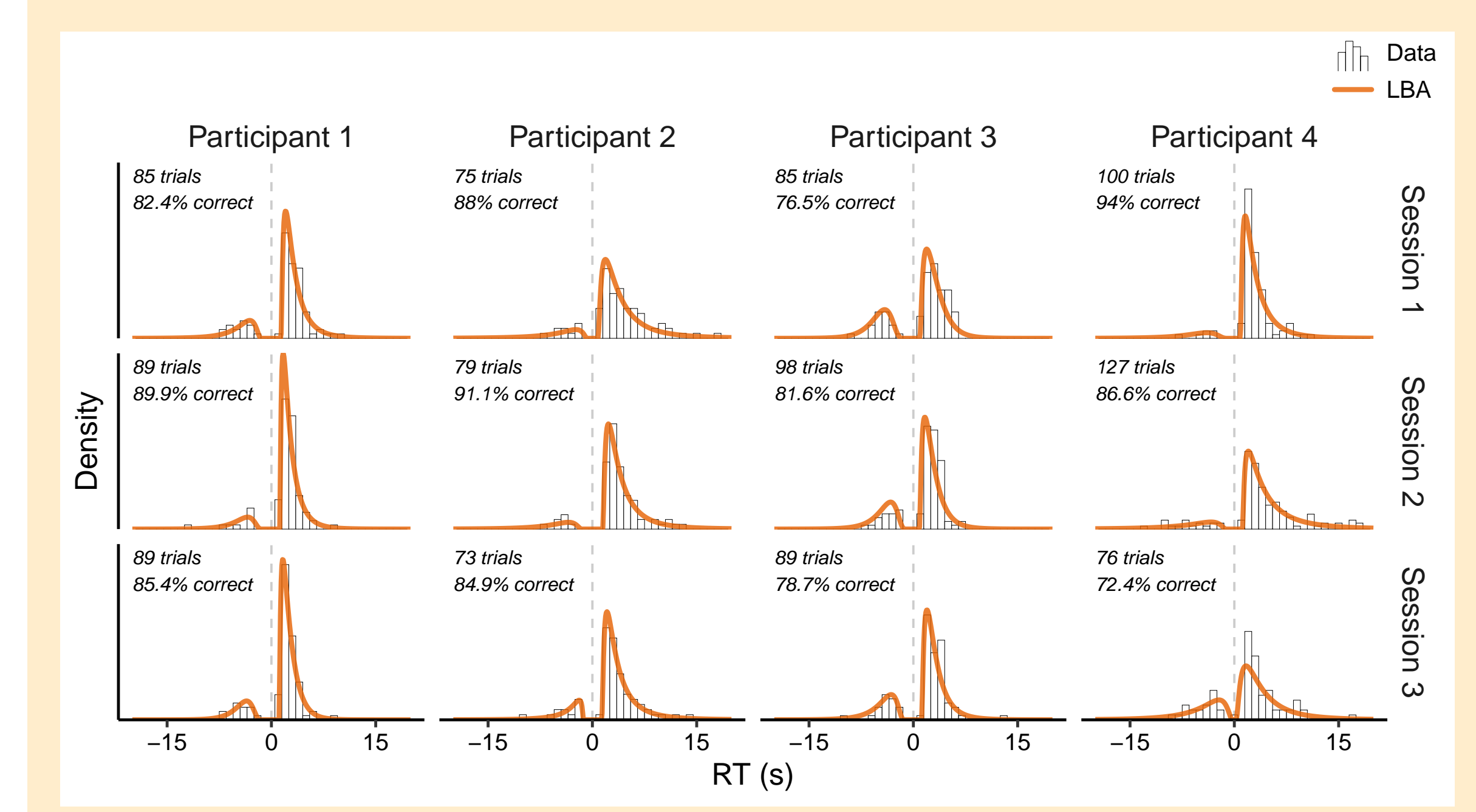


▣ Recovery of ACT-R parameters using the LBA. **A:** Original versus recovered parameter values for a data set with 100 trials per participant. **B:** Recovery accuracy (absolute error) for data sets with different numbers of trials per participant. Light coloured points show individual errors, dark coloured points show the mean error per parameter, and black points show the mean error across parameters. The grey bar marks the data set shown in sub-figure A. **C:** Correlation (Pearson's r) between original and recovered parameter values for data sets with different numbers of trials per participant. Coloured points show the correlation per parameter, and black points show the mean correlation across parameters. The grey bar marks the data set shown in sub-figure A. **D:** Correlations (Pearson's r) between pairs of recovered parameters in the data set with 50,000 trials per participant.

Empirical example: estimating parameters

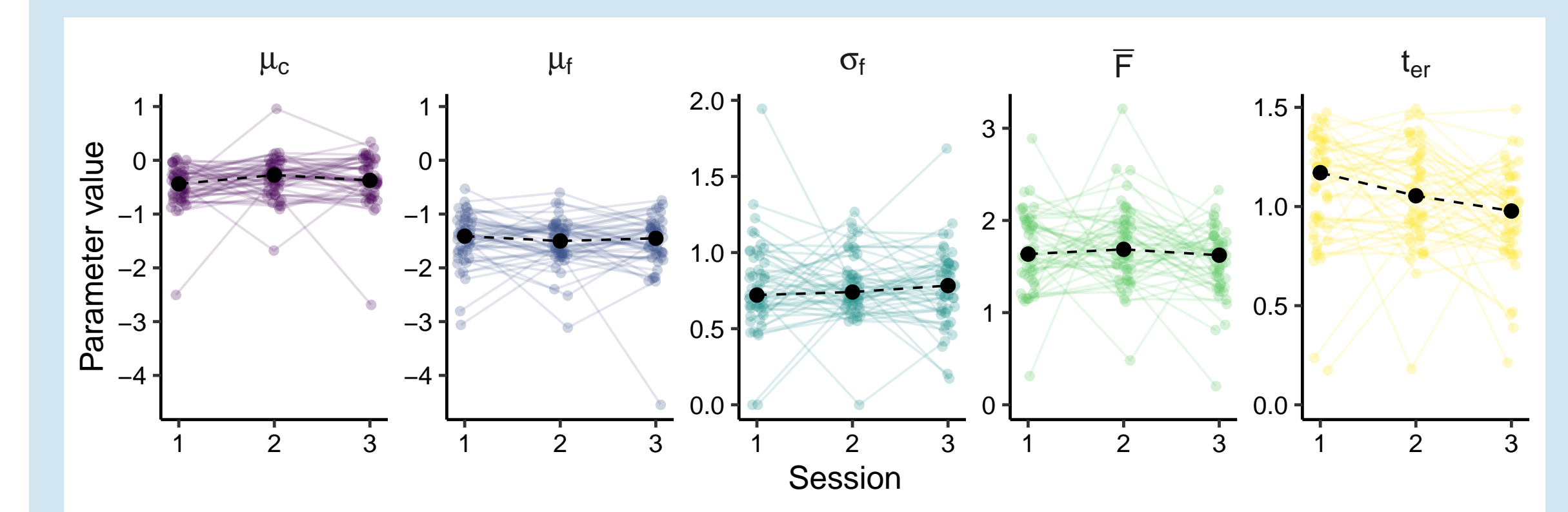


▣ Performance on a **three-session retrieval practice task** (right), $n = 50$. **A:** percentage correct responses. **B:** median response time on correct responses.



▣ Example fits of the LBA to the response data of four participants.

Faster, more accurate responses can be explained through a **larger difference in activation** between answer options ($S1 \rightarrow S2$) and a **drop in non-retrieval time** ($S2 \rightarrow S3$).



▣ ACT-R memory parameters inferred from the data. Coloured points show individual estimates; large black points indicate the median value across participants.

More information

Read the paper: psyarxiv.com/yg7s6

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