# Revisiting a Critical Period for L2 Acquisition

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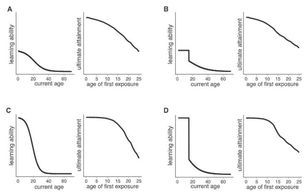
## Introduction

- How does the ability to learn syntax change over time, and is there a “critical period” in which language learning abilities are at peak?
- Previous studies had studied **ultimate attainment** as opposed to the **learning rate** [6]



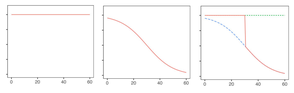

- Lab experiments biased by the fact that adults learn much faster than children at first
- Conducting inference on these questions requires large statistical power

## Background

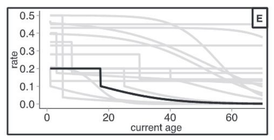
- Hartshorne, Tenenbaum, Pinker (2018) collected a large dataset (n=669,478) using an online viral quiz, in which participants answered questions about English grammar [5]
- Computational model in which grammatical proficiency was related to the **integral** of the language learning curve

$$g(t) = 1 - e^{\int_{t_e}^{t} -Erdt}$$

$$r = \begin{cases} r_0 & t \leq t_e \\ r_0(1 - \frac{1}{1+e^{-\alpha_2(t-t_e-d_2)}}) & t > t_e \end{cases}$$



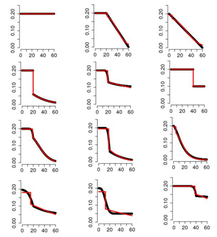
- Second language learning ability was found to undergo a sharp drop at around 17.4 years




## Method

### Potential Limitations of HTP 2018

- Strict shape assumptions on the language learning curve
- Limited the flexibility and expressiveness of the model
- Used a log-odds transformation (elogit) to measure grammatical ability
- Gives equal weight to each item



Curve recovery for the HTP model

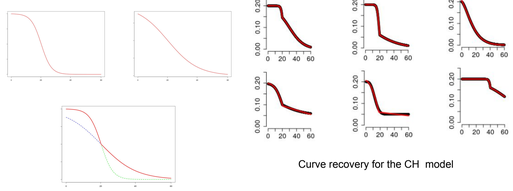
### The New Model

- Re-analyzed HTP data, with an additional 466,607 subjects (**total N=1,136,105**)
- More flexible analytic model, produced by a mixture of two sigmoids

$$g(t) = 1 - e^{\int_{t_e}^{t} -Erdt}$$

$$r = \begin{cases} r_0(1 - \frac{1}{1+e^{-a_1(t-t_e-d_1)}}) & t \leq t_a \\ r_0(1 - \frac{1}{1+e^{-a_2(t-t_e-d_2)}}) & t > t_a \end{cases}$$

$$t_a = \frac{a_1 * d_1 - a_2 * d_2}{a_1 - a_2}$$

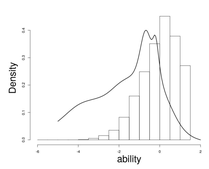


Curve recovery for the CH model

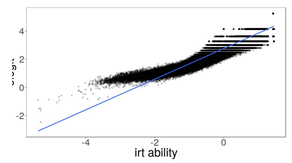
- Employed Item Response Theory for more fine-grained measurements of grammatical proficiency
- Allows for estimation of latent factor scores for each individual

## Results

- Fit a three parameter IRT model and extracted the latent ability estimates

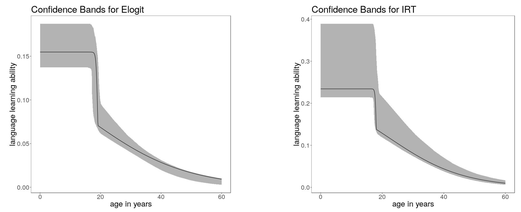



*Histogram of extracted Item Response Theory ability scores, overlaid with the test information curve*

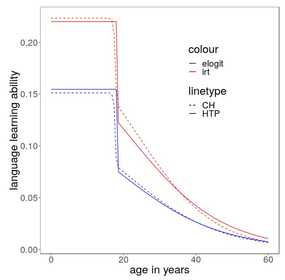



*Scatterplot of irt ability scores vs elogit scores*

- Models fit using differential evolution [7]
- Calculated bootstrapped confidence intervals for parameters




Bootstrapped confidence bands for the CH models, using elogit (left) and IRT (right) as ability measures




*Best fit language-learning curves for fitted models.*

| Ability Estimate | Model Type | $R^2$ | Critical age (95% CI) |
|---|---|---|---|
| IRT | New model (segmented-sigmoid) | .885 | 17.3 [16.5, 18.3] |
| IRT | Old model (HTP) | .885 | 18.1 [17.5, 18.8] |
| Elogit | New model (segmented-sigmoid) | .897 | 17.2 [16.3, 18.7] |
| Elogit | Old model (HTP) | .896 | 18.2 [17.6, 19.1] |

*Table of R-squared values and estimates of the critical age for each model*

## Conclusions

- The ability for humans to learn language undergoes a sharp drop at around 17-18 years of age
- Indicates that ~10 years is the oldest age to start learning a second language and still achieve native-like fluency
- All models gave similar predictions - the location of sharp discontinuity in language learning was predicted to be around 16-18 years of age
- Conclusions of HTP 2018 were validated and extended

## References

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