Longitudinal Multidimensional Item Response Modelling in Preschool Children's Mental State Understanding

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Theory of Mind (ToM)

Ability to perceive our own mental states as well as from others, such as beliefs, desires and intentions and know that they differ from one person to another.

- Developed in the first years of life (4 years old).
- Allows to understand social environment and how to interact in it.
- Different mental state tasks to identify the acquisition of ToM in children.

Figure 1: Sally-Anne task

Multidimensional Item Response Theory (MIRT)

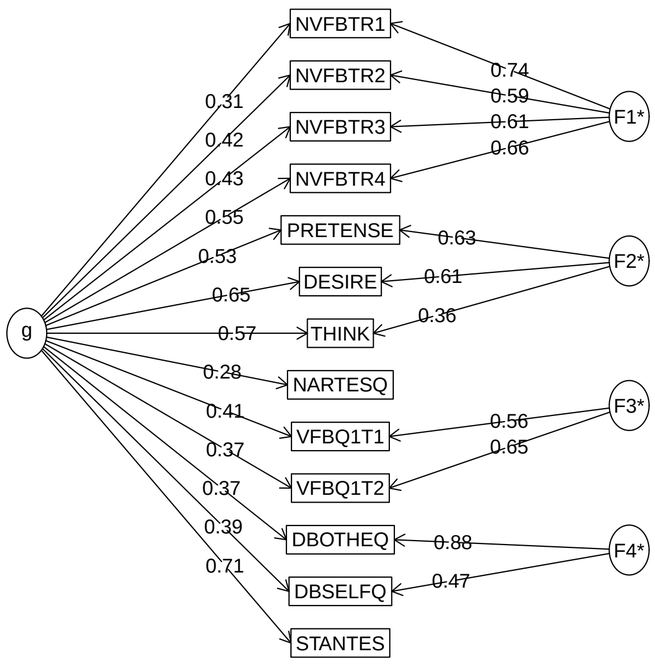

Figure 4: Bifactor model Path. Use of `psych` package to do the structure, but not the output numbers.

1. **Exploratory Factor Analysis**
   - Not previous knowledge of the number of dimensions that comprises ToM.
   - Dimensions estimated by comparing nested models.
2. **Confirmatory Factor Analysis**

Bifactor model

A single factor is present in all the items, but with additional clusters of local dependencies formed by other independent specific factors.

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Main Findings

- Dimensional reduction of ToM general ability.
- ToM is comprised by 6 latent dimensions.

Overview

1. Aim

Understanding of mental states in children over the third year of life, that is over a year before they are supposed to pass belief tasks, through MIRT.

2. Data Description

Participants

86 British children (Female = 41, Male = 45) from different preschools and day nurseries located in Northern Lancashire. Age: Between 30 and 33 months when recruited.

Measures

8 mental state tasks (13 questions three times in intervals of 4 months). A correct response scored '1' and an incorrect response scored '0'.

- Standard Location Change
- Deceptive Box
- Narrative
- Pretense, Desire and Think
- Verbal and Non Verbal (2 and 4 trials respectively)

3. Non-Longitudinal Analysis

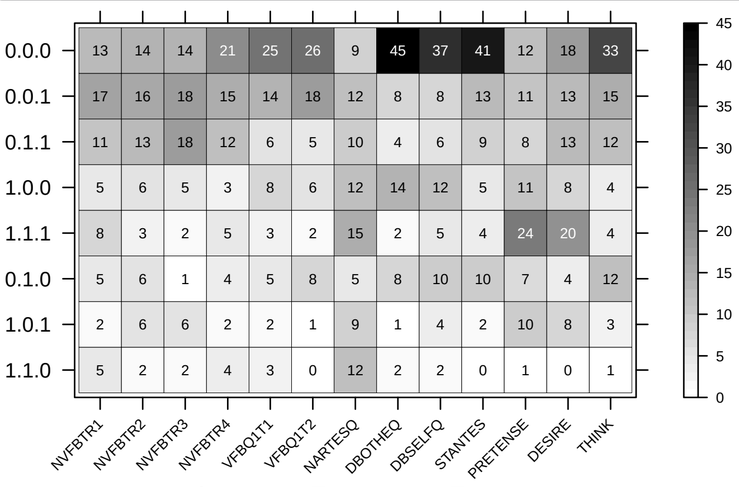

Figure 2: Response Patterns

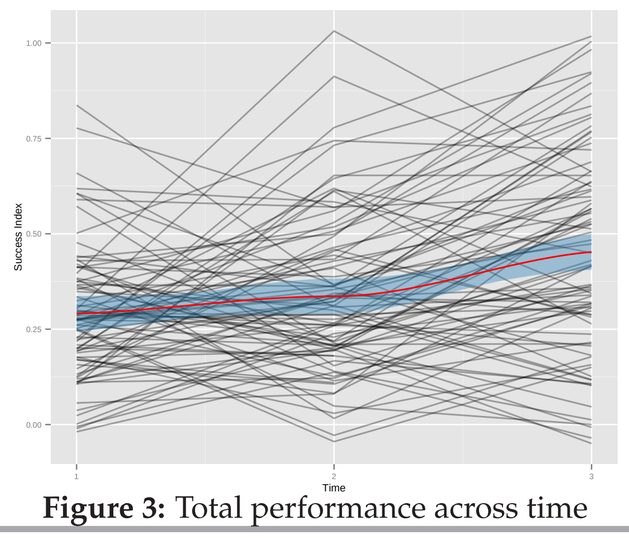

Figure 3: Total performance across time

The Two Stage Approach to determine Causality

First Stage: Bayesian Longitudinal Analysis

Features of Modelling

- **Correlation Structure:** Latent abilities on the same subject will be more correlated than among different subjects.
  - Autoregressive AR(1)
  - Unstructured Covariance
  - Random Effects
- 3 chains of 10000 iterations with a burn-in phase of 5000 and final results pooled in a single chain.
- Employment of a **BUGS** (**B**ayesian inference **U**sing **G**ibbs **S**ampling) code called from the free software R.

Model Selection

Table 1: Summary of DIC criterion

Model	DIC	$Q_{0.025}$	$Q_{0.975}$
AR(1) Covariance Structure	2312.46	2205.88	2418.96
Unstructured Covariance	2242.62	2124.69	2359.80
Random Effects	2337.56	2258.15	2415.93

- Smaller values of DIC suggests a better model.
- Final Model: AR(1) Covariance Structure

Estimation Results

Table 2: Summary of ρ estimate

Factor	$\bar{\rho}_f$	$Q_{0.025}$	$Q_{0.975}$
Non Verbal FB	0.44	0.22	0.63
Pretense, Desire, Think	0.65	0.43	0.83
Verbal FB	0.37	0.00	0.74
Deceptive Box	0.47	0.08	0.84
Narrative	0.06	-0.86	0.88
Location Change	0.62	-0.16	0.98

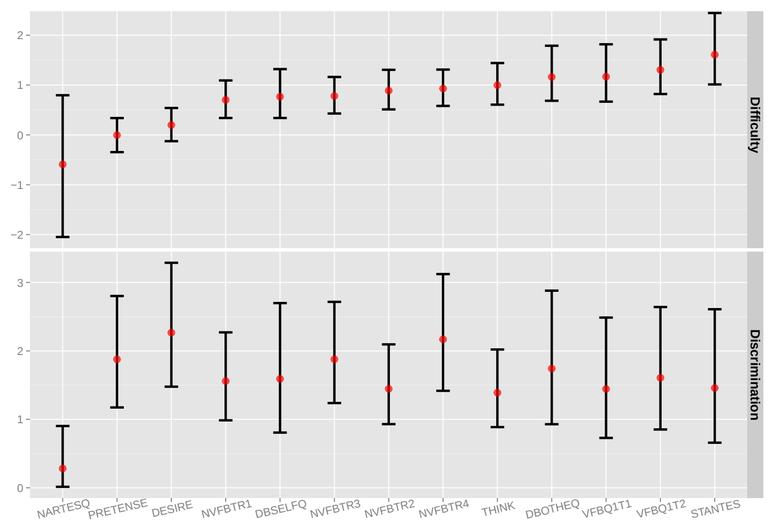

Figure 5: Credibility Interval of Item parameters considering AR(1) as covariance structure.

Second Stage: Ability Regression

Regression of the latent ability factors of $t = 2, 3$ against the latent ability of the previous instant of times.

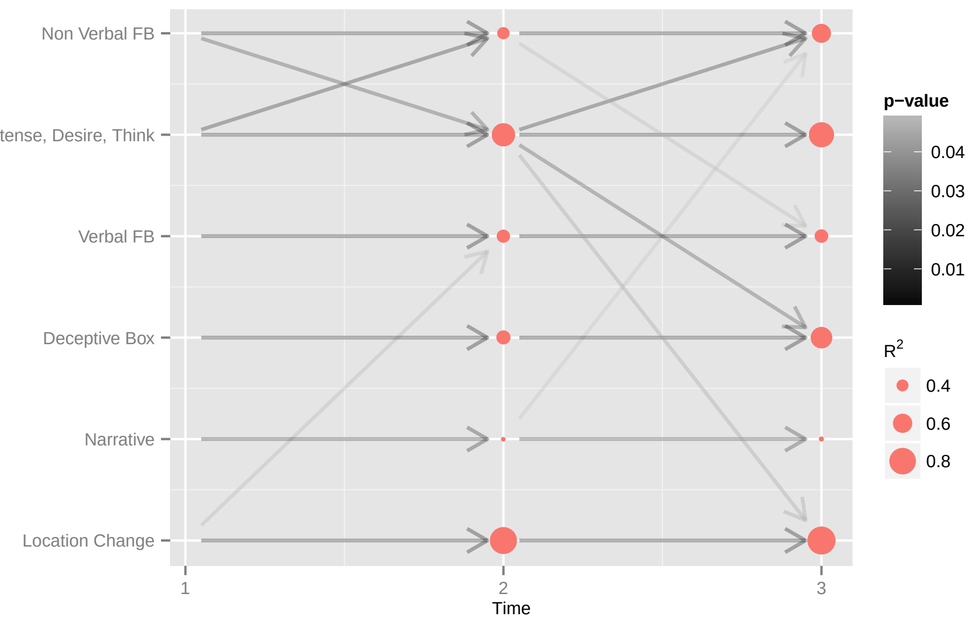

Figure 6: Path Diagram of Causality - Model AR(1).
The p-values have not been adjusted for multiple comparison.

References

[1] Curtis, S. M. (2010). BUGS code for item response theory. *Journal of Statistical Software*, 36:1-34.

[2] Revelle, W. (2015). The psych package Version 1.5.8. URL https://cran.r-project.org/web/packages/psych/psych.pdf

[3] Sturtz, S., Ligges, U., and Gelman, A. (2005). R2WinBUGS: A Package for Running WinBUGS from R. *Journal of Statistical Software*, 12(3):1-16. URLhttps://www.jstatsoft.org/article/view/v012i03

Conclusions

1. Children before 4 years old successfully passed Pretense, Desire and NVFB tasks.
2. ToM reduced to **6 latent abilities** through the Bifactor Model.
3. **Easy items:** Pretense and Desire. **Most difficult item:** Standard Location Change.
4. Significant improvement across time: NVFB ability.
5. **Causal analysis:** Pretense, Desire and Think affects the development of most of the others abilities.