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Longitudinal assessment of child behaviour based on three-way binary data

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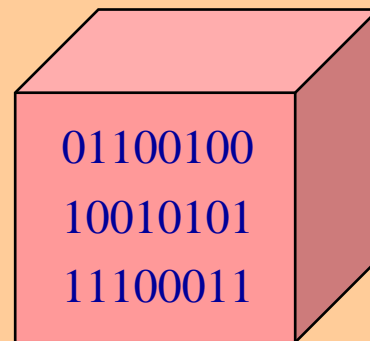
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Longitudinal Assessment of Child Behaviour based on Three-Way Binary Data: Episode 1



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Child Behaviour Check List

Basic three-way data

73 Children are scored on 108 behavioural items of the CBCL at 4 different time points

Three-point scales

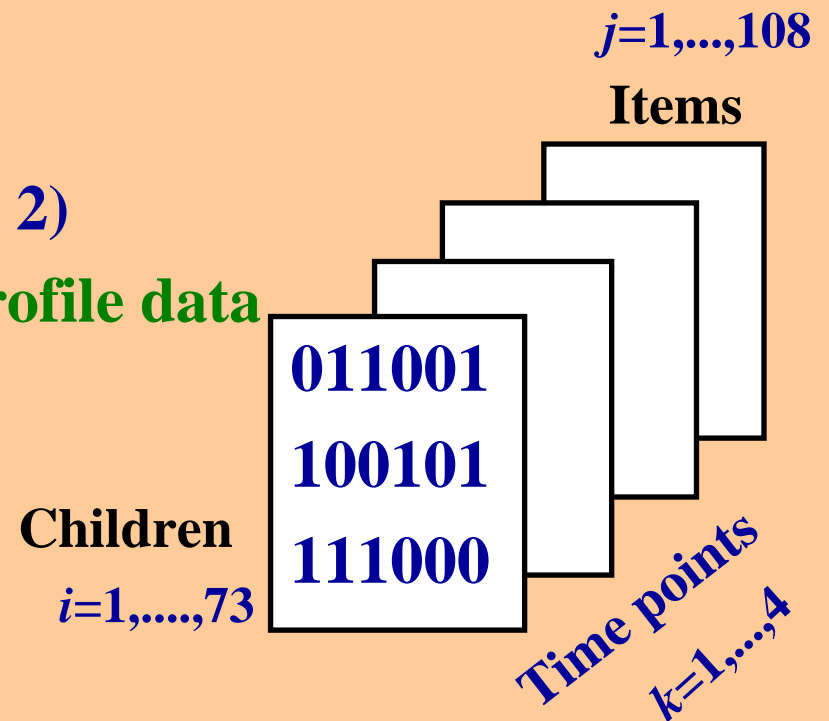
never (0), sometimes (1), often (2);
distributions terribly skewed

Binary data

does not occur (0); does occur (1 & 2)

Three-mode longitudinal binary profile data

Children \times Items \times Time Points



HICLAS3: Algebraic Representation

(Tucker3-HICLAS)

- Hiclas3 model (uses Boolean algebra)

$$\hat{x}_{ijk} = m_{ijk} = \bigoplus_{p=1}^P \bigoplus_{q=1}^Q \bigoplus_{r=1}^R \tilde{a}_{ip} \tilde{b}_{jq} \tilde{c}_{kr} \tilde{g}_{pqr}$$

- $m_{ijk} = 1$ iff $\tilde{a}_{ip} = 1$ and $\tilde{b}_{jq} = 1$ and $\tilde{c}_{kr} = 1$ and $\tilde{g}_{pqr} = 1$ for at least one combination of $p, q,$ and r
- $\tilde{a}_{ip}, \tilde{b}_{jq}, \tilde{c}_{kr}$: elements **binary** component matrices A, B, and C, respectively (Children, Items, Time points)
- \tilde{g}_{pqr} : element of the $P \times Q \times R$ three-way binary core array \mathcal{G} , indicates **links** between binary components of the three modes

HICLAS3 – Pictorial Representation

Children	Items	Time points	core array
A	B	C	
1	1 1	1 0	c1 a1 a2
2	0 1	1 1	b1 1 0
3	0 1	0 1	b2 0 1
4	1 0	0 0	
5	0 1		c2 a1 a2
6	0 0		b1 0 1
7	1 1		b2 0 1
8	1 0		

$m_{211} = 1$ as $a_{22}b_{12}c_{11}g_{221} = 1 \times 1 \times 1 \times 1$
 (all other 7 combinations contain a zero)

Three-Mode Component Analysis

- Tucker3 model (numerical)

$$\hat{x}_{ijk} = m_{ijk} = \sum_{p=1}^P \sum_{q=1}^Q \sum_{r=1}^R a_{ip} b_{jq} c_{kr} g_{pqr}$$

- $i=1,\dots,I$ (children); $j=1,\dots,J$ (items); $k=1,\dots,K$ (time points);
- m_{ijk} is the **model matrix or structural image**
- a_{ip} , b_{jq} , c_{kr} : elements **loading matrices** A, B, and C, respectively (children, items, time points).
- g_{pqr} : element of the $P \times Q \times R$ **three-way core array** \mathcal{G} ; indicates strength of the link between the components of the three modes

Three-Mode Binary Analysis in Action

**Changes in child behaviour
over time measured with the
Child Behaviour Check List
(Achenbach)**

Sample

73 children

Select subsample from a larger Dutch study.

Only children who were measured four time with the same instrument.

Sample is too small to make definitive statements about the structure of the items in the 108 item questionnaire

Items

Child (problem) behaviours

Binary answers – occurs (0) or does not occur (1)

Externalising problem behaviour

- ☞ Child is oppositional (OP)
- ☞ Child is aggressive (AG)
- ☞ Child is overactive (OV)

Internalising problem behaviour

- ☞ Child is withdrawn/depressed (WD)
- ☞ Child is anxious (AN)

Medical, sleeping problems and special behaviours

Points in time

Four measurements

- ∞ **Time 0:** child is between 1.5 and 5 yrs old
(from a substantive point of view age range is far from ideal)
- ∞ **Time 1:** 6 month after T0
- ∞ **Time 2:** 9 months after T0
- ∞ **Time 3:** 12 months after T0

Expectations about changes between time points T1-T3 are low given their closeness

Data: Children \times Items \times Time

(73 \times 108 \times 4)

$j=1,\dots,108$

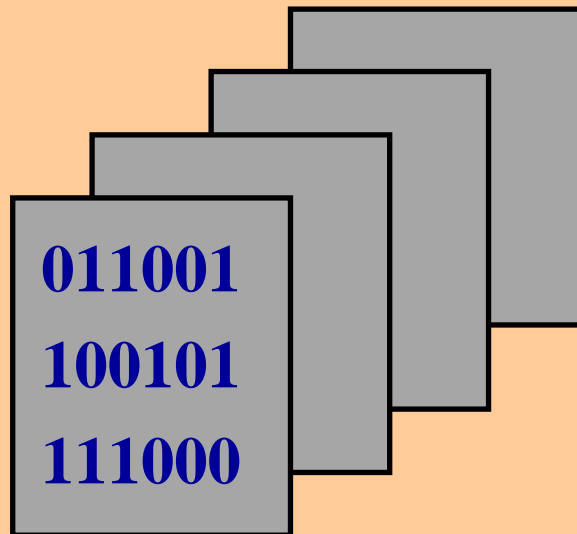
Items

MODE B

$i=1,\dots,73$

Children

MODE A



$k=1,\dots,4$

Years

MODE C

Changes in Problem Behaviour

Central questions

- ∞ In which way do the items group? Is this related to the original (theoretical) grouping/components?
- ∞ How do the children group and how many groups can the data sustain?
- ∞ Do different groups of children have different patterns for grouping the items?
- ∞ Do the item groupings change over time?

HiClas3 Model

Tucker3 hierarchical classes model

Basic elements

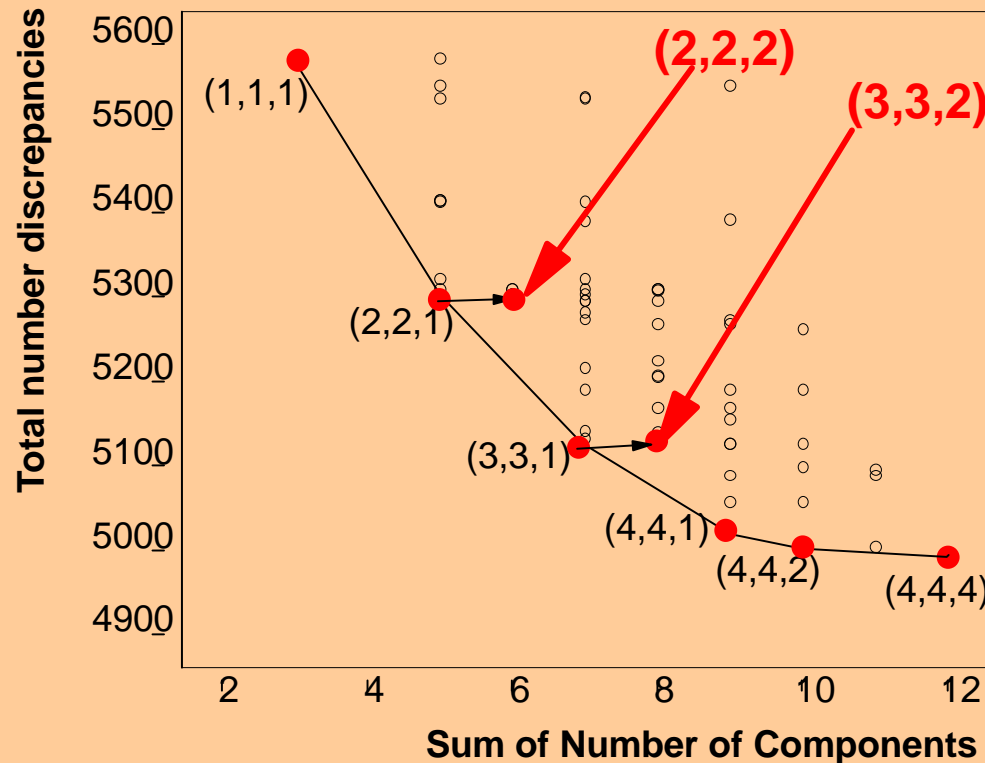
- ❧ Binary components for all three modes (children, items, years)
- ❧ Plus linkage information about the components

Basic literature

- ❧ Papers by Ceulemans, Van Mechelen and others (Catholic University Leuven, Belgium).
- ❧ *Psychometrika & British Journal of Mathematical and Statistical Psychology*

HiClas3 – Choosing a Model

Children \times Items \times Time Points



Model complexity: (3,3,2) = (Children = 3 components ; Items = 3; Time Points = 2)

Discrepancy : Data have a 1, model matrix has a 0, and vice versa

Choice of Model Complexity (Items)

Count

		H3_222				Total
		00	01	10	11	
H3_332	000	63	3	0	0	66
	001	14	7	0	0	21
	100	0	6	2	2	10
	101	0	3	0	0	3
	111	0	0	1	7	8
Total		77	19	3	9	108

		H3_222				Total
		00	01	10	11	
H3_442	0000	68	0	0	0	68
	0001	6	2	0	0	8
	0010	0	9	0	0	9
	0011	1	0	1	0	2
	1000	1	5	1	1	8
	1001	1	1	1	0	3
	1010	0	2	0	0	2
	1100	0	0	0	1	1
	1101	0	0	0	2	2
	1110	0	0	0	1	1
	1111	0	0	0	4	4
	Total		77	19	3	9

Binary Component Matrices (items, time)

Items

Class M 1 2 3

Class 1	.11	0	0	0	66	other behaviours
Class 2	.26	0	0	1	21	fearful, unsettles, sleeping problems
Class 3	.40	1	0	0	10	temperamental, lack of concentration, moods
Class 4	.40	1	0	1	3	frustrated, whining
Class 5	.62	1	1	1	8	disobedient, wants attention, demanding

Time points Follow-up Start

Time 1	0	0	1
Time 2	+ 6	1	0
Time 3	+ 9	1	0
Time 4	+12	1	0

Classes do not correspond to standard item grouping of the CBCL

M = mean = proportion of 1s

Binary Components

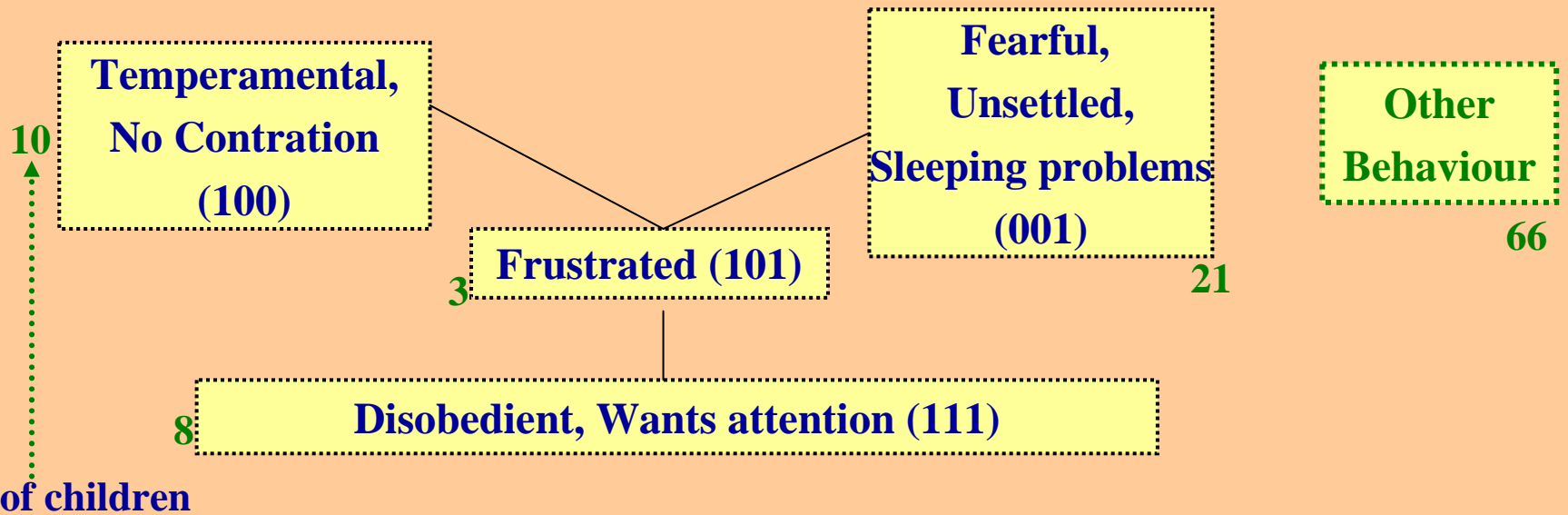
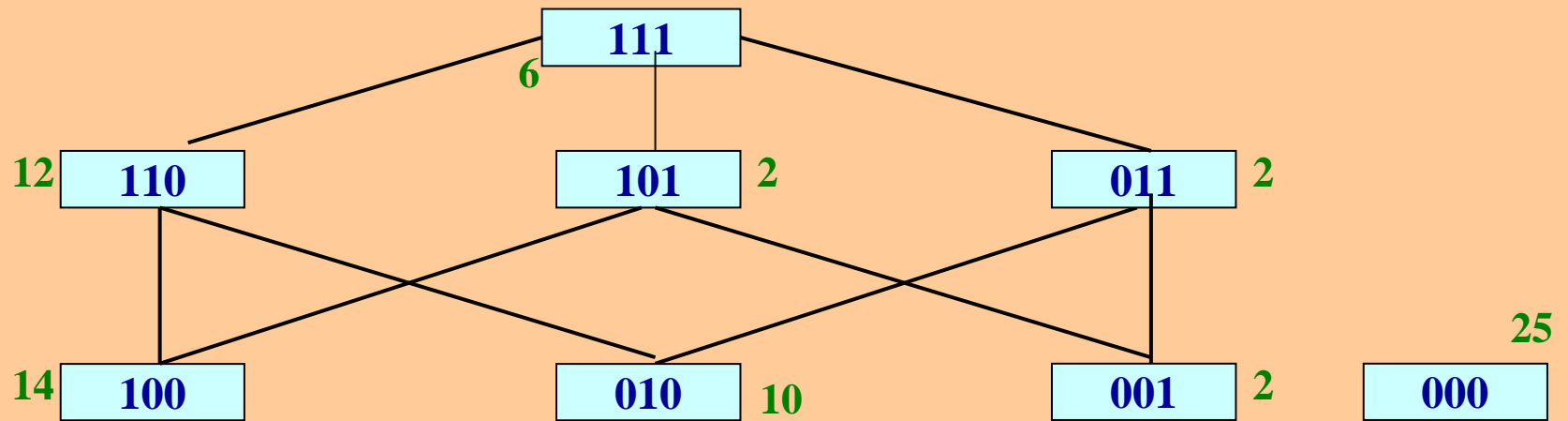
(children)

child Classes	M	1	2	3	<i>f</i>	
Class 1	.10	0	0	0	25	children without problems?
Class 2	.19	0	1	0	10	
Class 3	.23	0	0	1	2	
Class 4	.23	1	0	0	14	
Class 5	.28	1	1	0	12	
Class 6	.31	0	1	1	2	
Class 7	.39	1	0	1	2	
Class 8	.41	1	1	1	6	

M = mean = proportions of 1s

Hierarchical Trees

(Children and Items)



Binary Core Array (linking the components)

Start (0 1) Item1 Item2 Item3
 Temperamental
 Disobedient
 Fearful

Ch 1 0 0 0
Ch 2 1 1 0
Ch 3 0 1 1

Follow-up (1 0)

Ch 1 1 1 0
Ch 2 0 1 0
Ch 3 0 1 0

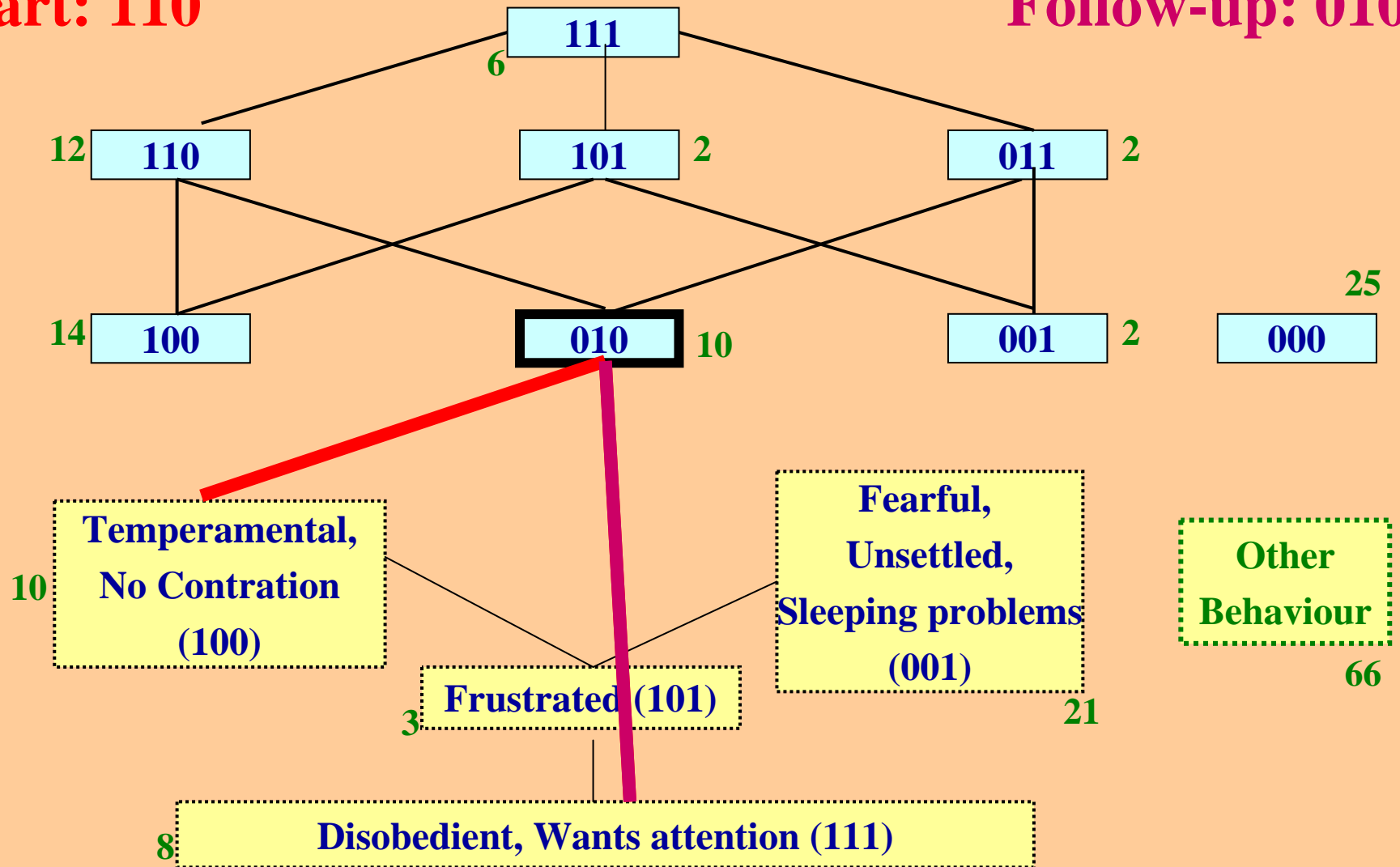
1 : a link exists between
components of the three
modes

Hierarchical Trees

(Child 2 Component)

Start: 110

Follow-up: 010

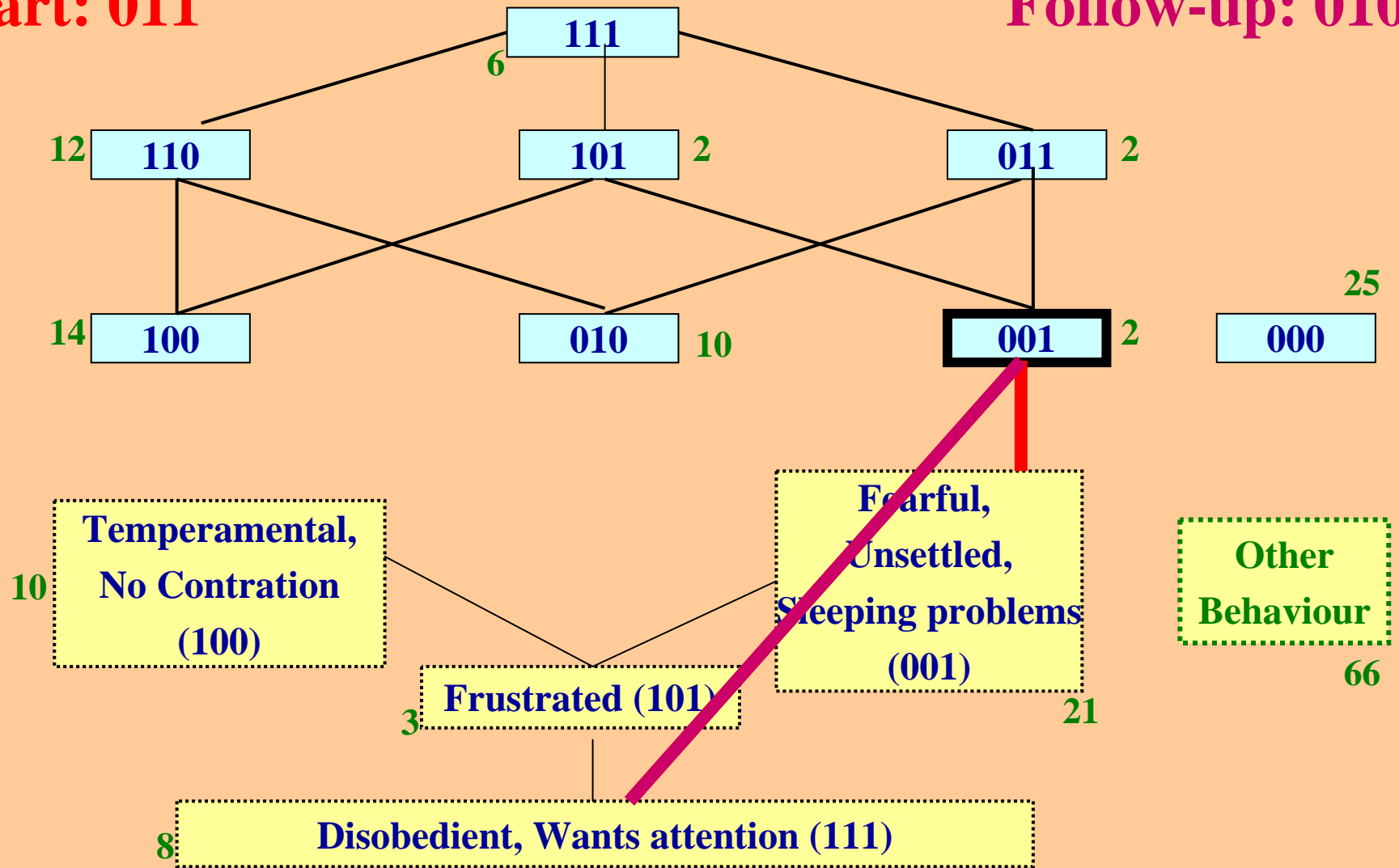


Hierarchical Trees

(Children and Items)

Start: 011

Follow-up: 010



Questions - 1

- ❧ What to think of the large number of items not modelled?
- ❧ What to think of the large number of children not modelled?
- ❧ How to examine solutions with different numbers of components, in particular the different hierarchical classes generate by them?
 - 1 component - 2 classes
 - 2 components - 4 classes
 - 3 components - 8 classes
 - 4 components - 16 classes
- ❧ Are these classes nested across analyses?
- ❧ Why is the standard group structure of the CBCL not found?

Questions - 2

- ∞ **The algorithm is a combinatorial one with many local minima.
How to evaluate the equivalence or differences of a 100 solutions with each, say, 8 differences classes in both row and column mode?**
- ∞ **Which type of data are primarily suitable for HiClas models?
Three-mode stimulus – response data (= three-mode rating data)?
Three-mode profile data (as presented here)?**
- ∞ **Is the number of rows compared to columns relevant for the fitting of the HiClas model?**

Conclusions - HiClas analyses

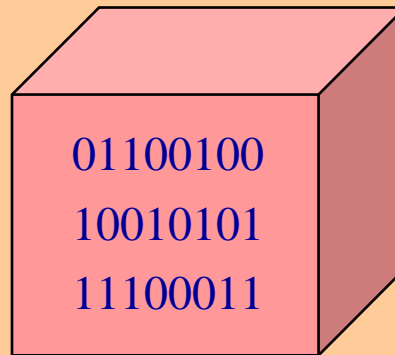
- **Given the data are binary, the binary hierarchical classes model is an obvious analysis method and often has a relatively straightforward interpretation.**
Less clear here due to data issues?
- **Effective graphics to display results**
- **Many components might be necessary to model all children and items, but a lot depends on the presence of sufficient number of 1s in the data**
No bricks (models) without straw (1s)

Conclusions - 2

Data

- ⇒ May be the data set is not the best to make inferences about the scale in general but how is one to know beforehand? May be also not for demonstration.
- ⇒ But what if I wanted to describe these data anyway?

**For the next Episode of this
Exciting Story
tune in next year at IMPS2009**



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