Categorial differentiation as a representational manifestation of recursion

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The Recursion Workshop (TAL, Cambridge)
18 June, 2024

Introduction

- This talk is about (i) **lesser-discussed facet of recursion** and (ii) a **hypothesis** for the **acquisition of syntactic (and other) categories**.
  (i) *Representational* and *ontological* manifestation of recursion → variously termed, **differentiation**, **granularisation**, etc.
  (ii) Differentiation proposed to be **key** in *emergent complex systems* → **expected to play a possibly important role in language too**.

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Syntactic categories *granularise* during language acquisition.
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→ **I show we observe evidence for (1) in syntactic acquisition**. Two case-studies to support it.

The many facets of recursion

Recursion

Definition of a problem or concept in terms of (a simpler version of) itself.
E.g., Fibonnaci sequence $F_n = F_{n-1} + F_{n-2}$ for $n > 1$ (Causey, 2006)

! Construed this way, recursion is a *function that could apply in many contexts.*

- Most commonly adduced *computational/derivational* manifestation of recursive functions in language: **self-embedding**, **Merge** (Hauser, Chomsky, and Fitch, 2002).

↪ Merge(A, B) → {A, B}, Merge ({A, B}, C) → {{A, B}, C}...

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→ **No reason to think the above is the only manifestation we should be caring about.**

The many facets of recursion

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Differentiation

Successive division or 'splitting' during development from a single, undifferentiated category or unit to progressively finer-grained/specialised categories/units.

- Recursive function that can apply over representations during development.

  $\text{Split(A)} \rightarrow \{\text{A, B}\}$, $\text{Split}(\{\text{A, B}\}) \rightarrow \{\{\text{A}, \{\text{A}_1, \text{A}_2\}\}, \{\text{B}, \{\text{B}_1, \text{B}_2\}\}\}$

The plan for today

Differentiation in emergent systems

- Several indications that differentiation plays a key role in various cognitive and biological domains.

→ **Embryogenesis**: **differentiation** of cells to a new cell type throughout development, from **more *general* to more *specific*** (R. Gordon and N. K. Gordon, 2019).

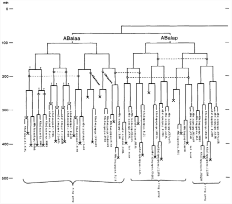


Figure 1: Cell lineage tree

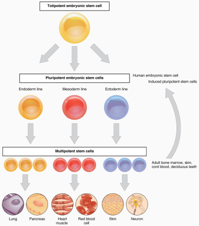


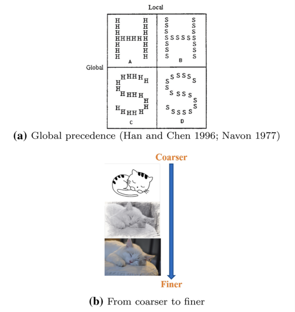
Figure 2: Cellular differentiation

→ **Visual perception**:

- **Global precedence effect** (Han and Chen, 1996; Chen, Zhang, and Srinivasan, 2003; Chen, 1982): global level in object perception recognised before local level, local disregarded for global information.

↪ Basis for coarse-to-fine (CtF) processing work (see Musel et al., 2014, for a review).

↪ Global processing may **predominate** in infants as young as **3 months** (Ghim and Eimas, 1988; Bhatt, Rovee-Collier, and Shyi, 1994; Freedland and Dannemiller, 1996), and is possibly ***absent* outside humans** (Aust and Braunöder, 2015).



(a) Global precedence (Han and Chen 1996; Navon 1977)

(b) From coarser to finer

Figure 3: Human cognition: from coarser granularity levels to finer levels (Wang, 2017, p. 348)

→ **Visual perception**:

- **Recognition-by-components** (Biederman, 1987) and **Structural Information Theory** (Leeuwenberg and Helm, 2013): whole object is the *primary* 'code', object components are derived from this code via detecting regularities (Biberauer and Bosch, 2021).

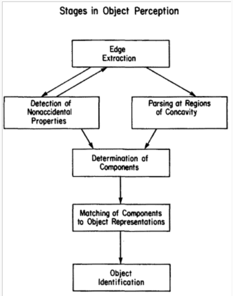
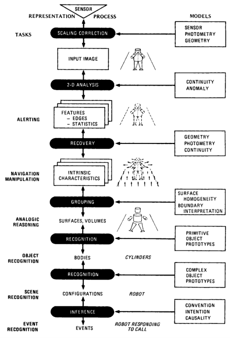


Figure 2. Presumed processing stages in object recognition.



→ **Categorisation**: categorisation is hierarchical.

- **Basic** and **superordinate** level categories acquired *before* subordinate ones (Horton and Markman, 1980; J. M. Mandler and Bauer, 1988; Mervis and Crisafi, 1982).
- Participants spontaneously categorise and abruptly converge on correct hierarchical categories (Frank et al., 2023).

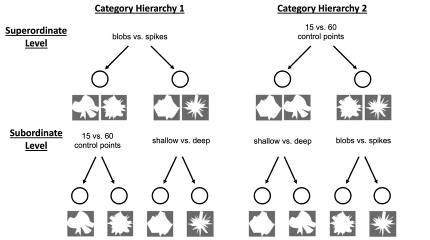


FIGURE 2 Categorization rules for superordinate and subordinate levels of the two hierarchies with sample stimuli. Note that the same stimulus set was used for both hierarchies, but the categorization of the stimuli changed with the rules of the hierarchy.

Differentiation in emergent systems

→ **Categorisation**: categorisation is hierarchical.

- **'Weak central coherence'** in **autism** → **cognitive granularity** as an informative characterisation of representation and neurological differences in autistic individuals ('too fine-grained') (Frith, 1989; Happé, 1999; Casanova et al., 2006; Kozima, 2013).

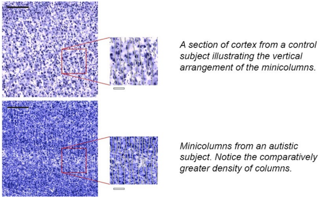


Figure 1. Differences in minicolumn density among individuals with ASD/HFA (Autism Science Foundation, 2015).

- (See also Rutar, Wolff, et al., 2022; Rutar, Wiese, and Kwisthout, 2022; Rutar, Colizoli, et al., 2023; Ward et al., 2023, for other very relevant work on **Bayesian structure learning**).

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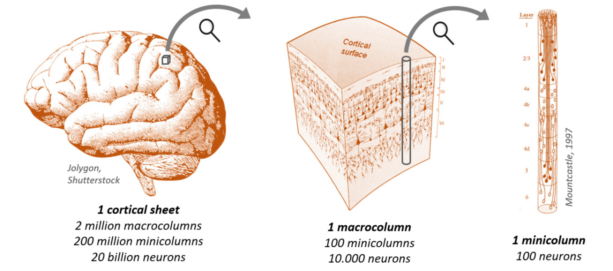

Differentiation in emergent systems

- If cognition granular, decision-making processes can 'latch on' to the most appropriate levels of granularity/analysis, esp. under certainty.

→ **Decision making and information processing**:
  - **Granulation** — an operation to construct or decompose already-existing granules (Zadeh, 1997).
  - Lorkowski and Kreinovich (2015) on **optimisation under granularity**:
    - Decision making *superficially* irrational (see, i.a., so-called satisficing, heuristics-and-biases, bounded rationality literature).
    - Can be explained: processing operates not with exact values of different quantities, *but more general granules (partial information)* that contain these values.
  - M. Mandler (2020) **coarser is better**: efficiency enhanced by letting coarse criteria—criteria with fewer categories—replace fine criteria.

Differentiation in emergent systems

- Overall:
  - Embryogenesis
  - Visual perception
  - Categorisation
  - Decision-making and information processing

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→ **ALL: From *coarse* to *fine***.

- Converge on the observation that cognition/biology organised 'granularly' and through differentiation, a *type of recursion.*
- Decision making and information processing appear to harness the granular levels at its disposal to optimise resources.

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↪ **Hierarchical categorisation central in human cognition and development**.

Differentiation, abstractly

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- **(Memory) Evolutive Systems** (Ehresmann and Vanbremeersch, 2007; Ehresmann and Vanbremeersch, 2019): category-theoretic and systems-theoretic of why complex systems are granular.
    - Which systems? Many! Biological (e.g., cellular), cognitive, economical, sociological...
    - Complex Adaptive Systems are:
        - (i) Emergent, self-organising.
        - (ii) Structurally homologous or ‘multiplex’.
        - (iii) *Granularise* through complexification processes (functor f from $\mathcal{C}_1 \to \mathcal{C}_2$).

Differentiation, abstractly

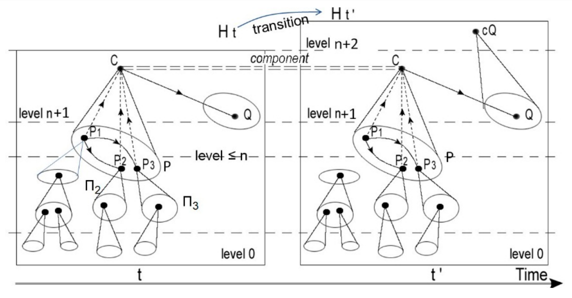
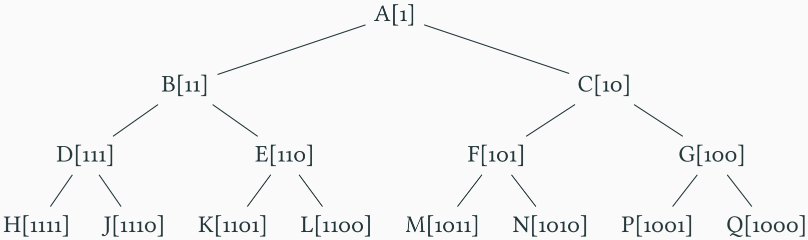


Figure 4: Transition from two hierarchical Categories in a Hierarchical Evolutive system

Differentiation, abstractly

- Douglas (2024) → emergent (linguistic) categories arise through *differentiation*.
- *Differentiation tree*, with its *differentiation code*, encoding its developmental sequence. **Coarse** to **fine**.



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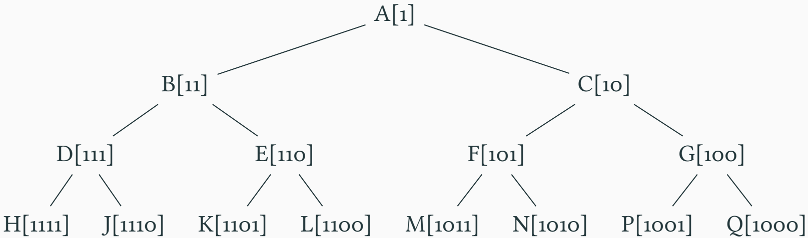

↪ **These works, among others, give us a language-general framework with which to understand linguistic data (Bosch, 2023)**

Two case-studies

- Recall:

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Syntactic categories *granularise* during language acquisition. Acquisition proceeds such that coarser-grained categories are acquired first, with later, finer-grained distinctions elaborating on developmentally-prior structure.

Differentiation as an acquisitional hypothesis: two case-studies

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Syntactic categories *granularise* during language acquisition. Acquisition proceeds such that coarser-grained categories are acquired first, with later, finer-grained distinctions elaborating on developmentally-prior structure.

- ***Strong* hypothesis**: expands on existing work arguing for granularity-aware linguistic analyses (i.a., Dresher, 2009; Jaspers, 2012; Biberauer and Roberts, 2015; Song, 2019; Cournane and Klævik-Pettersen, 2023), but **takes it one step further**, arguing this **reflects *language acquisition*** (following Biberauer and Roberts, 2015).

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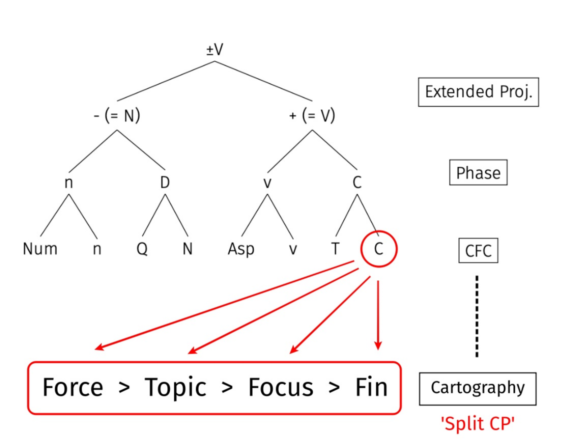
- If true, we expect:
    - Coarser-grained categorial distinctions acquired *earlier* than finer-grained ones.
- Brief evidence now from:
    - Acquisition of functional sequencies (esp. cartography).
    - Crosslinguistic acquisition of topicalisation strategies (requiring more/less featural and categorial distinctions).

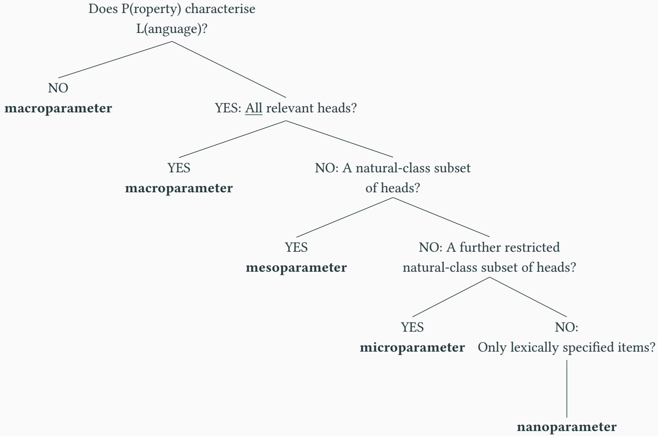
- Granularity/differentiation in ***formal feature postulation***: emergent categorial and parametric hierarchies in Biberauer and Roberts (2015).



Differentiation as an acquisitional hypothesis: two case-studies

- Granularity/differentiation in *formal feature postulation*: emergent categorial and parametric hierarchies in Biberauer and Roberts (2015).

(3) Schematisation of emergent parameter hierarchies



Differentiation as an acquisitional hypothesis: acquiring cartography

- *Granularity as an object of study*, not a *theoretical prior.*
- How can child data inform us about the granularity children may be operating with at different stages?

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- *Granularity as an object of study*, not a *theoretical prior*.
- How can child data inform us about the granularity children may be operating with at different stages?
- **Case-study 1** (Bosch, 2023): emergence of **CP-structures** *vs* structures indicating command of a further articulated, **cartographic**-type CP ('**Split CP**' structures). **10 monolinguals, 5 languages**.

- **CP diagnostics**:
  1. Wh-questions
  2. Yes/no questions (Germanic only)
  3. V-to-C movement (Germanic only)
  4. Topics/Foci
  5. Illocutionary (main clause) complementisers (Romance only)
  6. Finite embedding

- **Split CP diagnostics** (Romance):
  1. Top > Wh
  2. Top > Top/Foc
  3. Complementiser > Wh/Top
  4. Quotative *que* 'that' > Wh (Ibero-Romance only)
  5. Topic > interrogative que 'that' (Catalan only)
  6. *Sí que/sì che* 'yes that' and *que sí que* 'that yes that' structures (for the latter, Ibero-Romance only)

Differentiation as an acquisitional hypothesis: acquiring cartography

- **Results**: CP-structures *early*, Split CP structures systematically *late*.

Table 1: Emergence of CP- *vs* Split CP-structures

	CP-structures	**Split CP-structures**
Laura	1;10.22	3;03.21
	1.15 MLUw	2.54 MLUw
Gisela	2;04.25	2;08.00
	1.58 MLUw	2.61 MLUw
Martina	1;08.02	2;04.13
	1.57 MLUw	2.69 MLUw
Rosa	1;07.13	2;10.14
	1.27 MLUw	2.5 MLUw
Irene	1;04.16	1;11.13
	1.32 MLUw	2.95 MLUw
Koki	1;07.20	2;04.18
	1.96 MLUw	2.69 MLUw
Kerstin	1;10.03	2;09.11
	1.28 MLUw	2.32 MLUw
Simone	1;09.11	2;06.23
	1.54 MLUw	2.78 MLUw
Josse	2;00.07	2;11.09
	1.2 MLUw	3.57 MLUw
Sarah	1;10.05	3;00.19
	1.09 MLUw	3.52 MLUw

Differentiation as an acquisitional hypothesis: acquiring cartography

Age	MLUw	S-Neg-V	S-Adv-V	S-Cl-V	Aux	Wh-Q	Top/Foc	Illoc	Embed	Split CP
1;07.20	1.03									
1;09.07	1.09									
1;10.22	1.15							✓		
1;11.12	1.15							✓		
2;02.05	1.35							✓		
2;02.13	1.3					✓				
2;04.11	1.44				✓	✓				
2;05.08	1.64									
2;06.25	1.76				✓	✓				
2;07.20	1.78	✓		✓	✓	✓		✓		
2;08.30	1.88			✓	✓	✓	✓	✓		
2;11.17	1.98	✓	✓		✓	✓	✓	✓		
3;00.02	2.42	✓		✓	✓	✓	✓	✓	✓	
3;03.21	3.47	✓		✓	✓	✓	✓	✓	✓	✓
3;05.13	2.54	✓		✓	✓	✓	✓	✓	✓	✓
3;10.00	2.97	✓		✓	✓	✓	✓	✓	✓	✓
3;10.01	2.91	✓		✓	✓	✓	✓	✓	✓	✓
3;11.12	3.0	✓		✓	✓	✓	✓	✓	✓	✓
4;00.10	3.18	✓	✓		✓	✓	✓	✓	✓	✓

Table 2: Production of structures by Laura (Catalan)

Age	MLUw	S-Neg-V	S-Adv-V	Aux	V2	Wh-Q	Y/N-Q	Top/Foc	Embed	Split CP
1;06.16	1.12									
1;07.21	1.17					Wh-less				
1;08.28	1.07									
1;09.10	1.17					Wh-less				
1;10.05	1.09				✓					
1;10.13	1.17				✓					
1;11.01	1.25				✓					
1;11.15	1.37				✓	Wh-less				
2;00.17	1.68	✓			✓		✓	✓		
2;01.10	1.88		✓	✓	✓		✓	✓		
2;02.18	2.11	✓	✓		✓	✓	✓			
2;03.16	2.05		✓	✓	✓	✓	✓			
2;04.02	2.53	✓	✓	✓	✓	✓	✓	✓		
2;04.09	2.34			✓	✓	✓	✓			
2;04.27	2.46	✓	✓	✓	✓	✓	✓	✓		
2;05.09	2.47	✓	✓	✓	✓	✓	✓	✓		
2;05.22	2.59		✓	✓	✓	✓	✓	✓		
2;06.04	2.74		✓	✓	✓	✓	✓	✓		
2;06.11	2.45	✓	✓	✓	✓		✓	✓		
2;06.18	2.8		✓	✓	✓	Wh-less	✓	✓		
2;07.16	2.51	✓	✓	✓	✓	✓	✓	✓		
2;08.06	2.66		✓	✓	✓	✓	✓	✓		
2;08.19	2.97	✓	✓	✓	✓	✓	✓	✓		
2;09.02	2.59	✓	✓	✓	✓	✓	✓	✓		
2;09.07	3.15	✓	✓	✓	✓	✓	✓	✓		
2;10.18	2.88	✓	✓	✓	✓	✓	✓	✓		
2;11.03	2.87	✓	✓	✓	✓	✓	✓	✓		
2;11.27	3.64	✓	✓	✓	✓	✓	✓	✓		
3;00.19	3.52	✓	✓	✓	✓	✓	✓	✓	✓	✓
3;01.17	3.06		✓	✓	✓	✓	✓	✓	✓	✓
3;02.13	3.82	✓	✓	✓		✓	✓	✓	✓	✓
3;03.21	3.05	✓	✓		✓	✓	✓	✓	✓	✓
3;04.13	3.15	✓	✓	✓	✓	✓	✓	✓	✓	✓
3;05.30	2.89	✓	✓	✓	✓	✓	✓	✓	✓	✓
3;07.25	3.24	✓	✓		✓	✓	✓	✓	✓	
3;10.07	3.71	✓	✓	✓	✓	✓	✓	✓	✓	✓
3;11.04	4.07	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;00.11	3.81	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;00.30	4.08	✓	✓	✓	✓	✓	✓	✓	✓	
4;01.11	4.66	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;03.04	5.37	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;04.28	4.28	✓	✓	✓	✓	✓	✓	✓	✓	
4;05.29	4.7	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;06.12	5.06	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;07.25	4.62	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;08.03	5.03	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;09.13	6.07	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;09.29	5.2	✓	✓	✓	✓	✓	✓	✓	✓	✓
4;11.15	4.01	✓	✓	✓	✓	✓	✓	✓	✓	✓
5;02.13	4.92	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 3: Production of structures by Sarah (Dutch)

Differentiation as an acquisitional hypothesis: acquiring cartography

- **Results**: CP-structures *early*, Split CP structures systematically *late*.

Table 4: CP-structures produced at Stages 1 + 2 and its length

	V2	Wh-Q	Y/N-Q	Top/Foc	Illoc	Embed	Length
Laura		15		4	42	4	1;10.22-3;03.21 (MLUw 1.15-2.54)
Gisela		1		0	6	0	2;04.25-2;08.00 (MLUw 1.58-2.61)
Martina		21		4	7	8	1;08.02-2;04.13 (MLUw 1.57-2.69)
Rosa		133		12	3	8	1;07.13-2;10.14 (MLUw 1.27-2.5)
Irene		18		3	10	4	1;04.16-1;11.13 (MLUw 1.32-2.95)
Koki		32		7	2	4	1;07.20-2;04.18 (MLUw 1.96-2.69)
Kerstin	✓	16	21	27		1	1;10.03-2;09.11 (MLUw 1.28-2.32)
Simone	✓	166	3	105		24	1;10.03-2;06.23 (MLUw 1.54-2.78)
Josse	✓	62	37	68		1	2;00.07-2;11.09 (MLUw 1.2-3.57)
Sarah	✓	124	104	116		0	1;10.05-3;00.19 (MLUw 1.09-3.52)

Differentiation as an acquisitional hypothesis: acquiring cartography

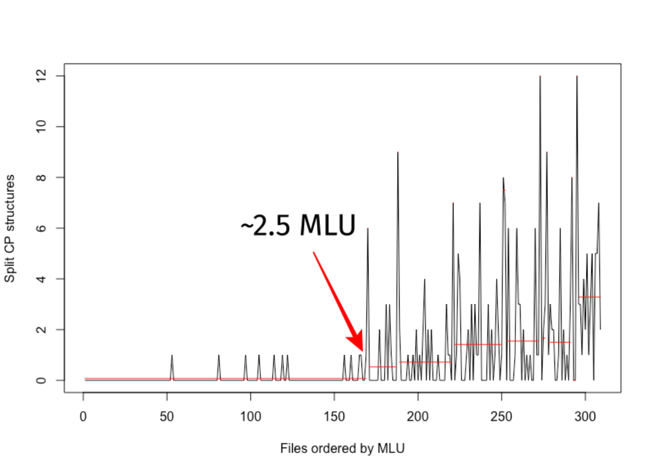
- **Results**: CP-structures *early*, Split CP structures systematically *late*.

Table 5: Production of Split CP-structures before and after MLUw ∼ 2.5

	Before MLUw ∼ 2.5	After MLUw ∼ 2.5	%
Laura	1	20	4.8-95.2%
Gisela	0	9	0-100%
Martina	0	5	0-100%
Rosa	1	31	3.1-96.9%
Irene	0	85	0-100%
Koki	0	41	0-100 %
Kerstin	3	4	42.9-57.1%
Simone	2	7	22.2-77.8%
Josse	1	19	5-95%
Sarah	2	51	3.8-96.2%
Total	10	272	3.5-96.5%

Differentiation as an acquisitional hypothesis: acquiring cartography

- **Results**: CP-structures *early*, Split CP structures systematically *late*.



→ Production data tells us that children harness cartographic-type knowledge significantly late and abruptly.

→ **My preliminary interpretation: cartography is 'learned', not innate.**

Generalisation 3: Cartography is Emergent

Evidence for cartographic-type structure within CP systematically and abruptly emerges at a later developmental stage, elaborating on developmentally-prior structure (a 'basic' CP).

Differentiation as an acquisitional hypothesis: topics crosslinguistically

- **Case-study 2**: crosslinguistic acquisiton of topics of varied parametric complexity.

↪ Topics often assumed to mature *universally* 'late' (i.a., Radford, 1990; Rizzi, 1993; Friedmann, Belletti, and Rizzi, 2021; Meira and Grolla, 2023).

Differentiation as an acquisitional hypothesis: topics crosslinguistically

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! **However, investigating the granularity and complexity of late topics reported for various L1s tells us this *isn't a universal*.**

Differentiation as an acquisitional hypothesis: topics crosslinguistically

- **Corpus study on Germanic-Romance bilinguals** → 'late' topics not a universal, L1-dependent pathways. Germanic topics have a clear advantage.

↪ Also borne out with **monolingual data** from a range of **typologically diverse** languages.

Table 6: Emergence of all CP-structures for both children

	V2	Wh-Q	Y/N-Q	Top/Foc	CLLD	Illoc	Embed
Heleen Italian		1;09.28		2;05.00	2;07.08	2;11.03	2;05.00
Heleen Dutch	1;09.11	1;09.11	1;09.11	1;11.00			2;02.18
Simon Spanish		2;05.24		2:08.06	3;03.12	2;05.24	3;00.10
Simon German	2;02.11	2;03.11	2;03.25	2;03.11			3;01.03

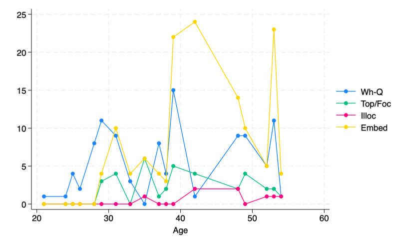


Figure 5: Development of CP-structures in Heleen's Italian

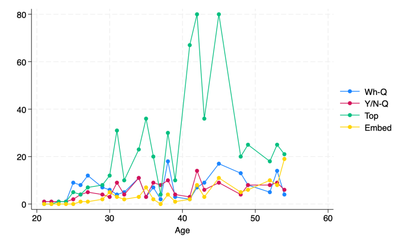
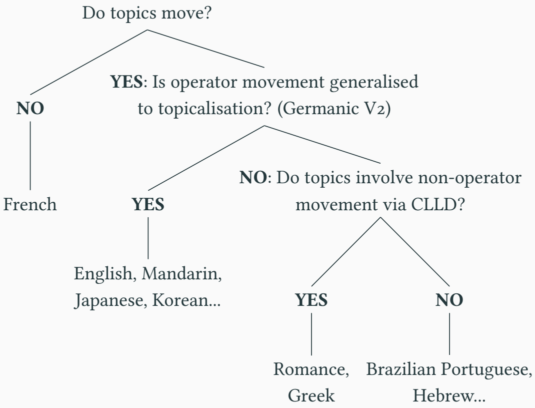


Figure 6: Development of CP-structures in Heleen's Dutch

Differentiation as an acquisitional hypothesis: topics crosslinguistically

- Why? I propose topics that require *parametrically* finer-grained distinctions acquired later → *non-operator* topics specifically are late.

(4) Parametric complexity in topicalisation structures



Differentiation as an acquisitional hypothesis: topics crosslinguistically

- Why? I propose topics that require *parametrically* finer-grained distinctions acquired later → **borne out crosslinguistically**.

Table 7: Topicalisation strategies, their acquisition and their formal complexity

Language	Acquisition	Formal characteristics of topicalisation	Parametric complexity
French	Very early	Adjoined or base-generated	Macroparameter
Germanic V2	Very early	Generalised V2 diacritic	Mesoparameter
Mandarin Japanese Korean	(Possibly) early	Operator movement or base-generation	Mesoparameter
European Portuguese	Early	Operator movement (non-CLLD only)	Mesoparameter
Spanish Italian Catalan	Late	Non-operator movement with CLLD	Microparameter
Greek	Late	Non-operator movement with CLLD	Microparameter
Hebrew Brazilian Portuguese	Late	Non-operator movement without CLLD	Microparameter

Differentiation as an acquisitional hypothesis: topics crosslinguistically

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→ **Acquisition timings follow from the parametric complexity ('granularity') of each topicalisation strategy**

Implications and outlook

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  - **Case-study 1**: granularity-aware data analysis tells us cartographic structure may be late-acquired.
  - **Case-study 2**: granularity-aware data analysis makes a fresh cut among data on the acquisition of topics crosslinguistically.

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↪ Why **granular thinking** is insightful:

  - Novel ways of approaching/conceptualising developmental data.
  - Unified treatment of hierarchical complexity in emergent systems.
  - Significant ramifications for linguistic categorisation and its ontological bases.
  - Implications for diachrony and computational work, i.a.
  - New perspective on ‘recursive’ functions in human language.

Thank you!

Acknowledgements: Special thanks to Theresa Biberauer and Bert Vaux for supervising, as well as the Open-Oxford-Cambridge AHRC DTP (UKRI) and St John's for supporting this work.

Slides 💻→

SCAN ME

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