What is Knowledge of Grammar? From Theory to Models and Back

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- Current LLMs finitize a grammar.
- What does that mean?
- A modern LLM: fixed (but VERY large) length of:

  - word vectors, input encoding, output decoding, input effect remembrance (attention)

- From ANNs (no retention), RNNs (50 epochs), LSTMs (1000), then to encoders-decoders, transformers (layers), attention,...

  - All are fixed in a deep and multi-layered NN architecture to facilitate standardized end-to-end modeling and training.

  - Restricting dependencies to a finite window (moving window or fixed window) also enables good semantic guesses.

Good enough for a linguist?

- A thought experiment: Indefinite-length mini-English from 4 orthographic words: I, you, think, like

- That's at least 7 words to a morphologist!
  I like you.
  You think I like you.
  I think you think I like you.
  *I like you like I like you.
  *I think you like I think you.
  I think you think I think you think I think I like you.
  *I think you think I think you think I think I like you think I like you.

- Size does not matter all that much, but what allows and disallows this embedding does.

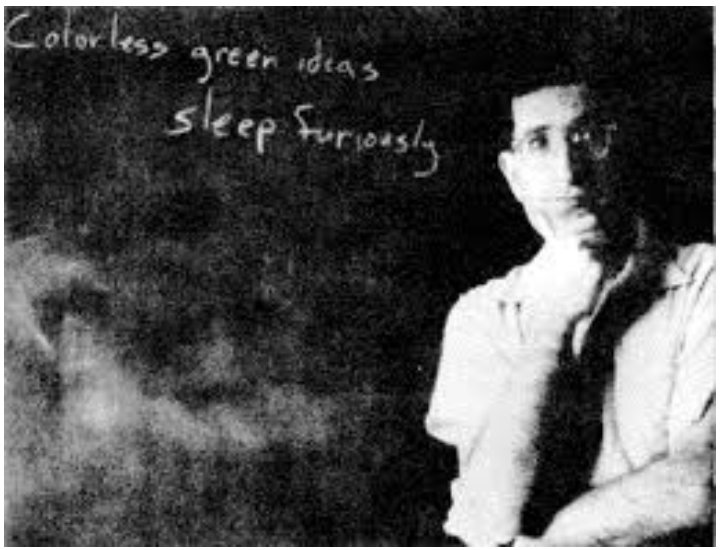
What do we expect from a model?

- Language technology: good, robust, reliable, and accessible performance.
- Linguistics: Putting an idea or theory about language to test.
  - Ever since antiquity, that usually means an idea or theory about grammar.
- Is it a coincidence that LLMs achieved such levels of performance by rising above the simplistic associationism of ANNs, adding layers and layers of abstraction?
  - much like a program or grammar

What is Knowledge of Grammar?

- The answer depends on what we expect from grammar.
  - Minimally, we want it to decide grammaticality (i.e. syntactic configuration).
  - Maximally, we would want it to cover everything under the sun about knowledge of language.
- Is this a matter of personal choice?
  - Every child exposed to NL data in the critical period acquires a natural language.
  - There are systematic exclusions if she is not.
  - Exclusions from what? Where do we show that?
  - Every native speaker has a sense of meaningfulness of an expression which is consequent to it being grammatical.

Colorless green ideas sleep furiously.



- NL grammars are representational spaces. Is this space limited?
- What is a linguistic category? Label? abstract, concrete?
- Anderson (1976): Data from ergativity and mixed systems show that the category space cannot be universally captured morphologically or surface-categorially (e.g. N, V, A, P).
- Categories in a grammar can be abstract objects (see Katz 1985 for a bit of philosophy of linguistics).

Some grammars as conceived by typologists and field linguists:

Ma Manda (Papua New Guinea, Papuan)

Mongsen Ao (Northeastern India, Tibeto-Burman)

North Paiwan (Taiwan, Austronesian)

Two related questions:

- Can we make human grammars (their proxies) determine grammaticality without external means?
- Or do we need extra means? (minimal links, mapping theories for multi-structures, multiple independent computations, movement management, subjacency, synch conditions, reanalysis, recomputation etc.)

The answer is critical: The more intermediaries there are, the more difficult it is to go from theory of grammar to models of grammar.

Scientific modellability is not a personal choice; but, perhaps modeling is.

One consequent question:

Is it enough to determine grammaticality?
(syntactic well-formedness)

The answer will determine what goes in to any NL grammar.

What kind of meaning must enter grammar?

Colorless green ideas sleep furiously.

- Wittgenstein
- Chomsky
- Leśniewski (1929)

- W: Language games can make it meaningful.
- C: It is already meaningful, because it is grammatical. What it lacks is sense.
- L: Categories are semantic in origin; no such thing as meaningless category.

1 If something is grammatical and senseful, we can think of world models for meaning.

- Ungrammatical ones are not meaningful to begin with:

  a. *Green sleep colorless furiously ideas

  b. *Hiç okumadığı Mehmet kitapları çok Ahmet'in seviyor Turkish

- This was (and is) a critique of studying meaning alone, or just probabilistically.

2 Where is the feel of meaningfulness coming from for senseless expressions?

- Categorial Grammarians have been drawing attention to a very striking asymmetry for far more than a century:[1]

  - Parts of a clause may require different categories,

    But one uniquely determines the clausal structure: The Verb

If the verb can determine clause's syntactic structure, it can also determine what makes it meaningful.

  - Maybe we can put grammatical categories, which are grammar's workhorses, to work on BOTH aspects.

[1] Husserl (1900); Sapir (1921); Ajdukiewicz (1935); Montague (1973); Schmerling (2018); Bozşahin (2025)

- Expressions with sense have intuitive world models (decision models, truth-conditional semantics).
- Expressions with no sense may have counter-intuitive but possible world models (possible world semantics).
- But these do not explain the feel of meaningfulness; they eschew the role of category choice in grammaticality:

choosing to refer to another event to the extent of affecting grammaticality.

(1) a. She played the piano for an hour/*in an hour. play
b. She played the sonata *for an hour/in an hour. perform
c. She played the sonata for a year. multiple perf.
d. She played the piano in a year. mastery
e. She played the piano in an hour. Genius?

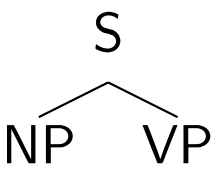
From distributional categories to abstract realities

$$\begin{aligned} \texttt{S} &\rightarrow \texttt{NP}\ \ \texttt{VP} \\ \texttt{VP} &\rightarrow \texttt{V}_{tv}\ \ \texttt{NP} \\ \texttt{V}_{tv} &\rightarrow \text{played} \end{aligned}$$

$$\begin{array}{lcl} \mathtt{S} & \rightarrow & \mathtt{NP}\ \ \mathtt{VP} \\ \mathtt{VP} & \rightarrow & \mathtt{V}_{tv}\ \ \mathtt{NP} \\ \mathtt{V}_{tv} & \rightarrow & \text{played} \end{array}$$

Looking top-down, they appear to be relations. Looking bottom-up, we can see that they are actually FUNCTIONS.

This is the first step toward understanding the verb's power.



$\mathtt{VP} = \mathtt{S}\backslash\mathtt{NP}$

$\mathtt{NP} = \mathtt{S}/\mathtt{VP}$

$\mathtt{V}_{tv} = \mathtt{VP}/\mathtt{NP} = (\mathtt{S}\backslash\mathtt{NP})/\mathtt{NP}$

Focusing on the verb, we get for example:

$$\textit{played} = \mathtt{V}_{tv} = (\mathtt{S}\backslash\mathtt{NP})/\mathtt{NP} : \lambda x \lambda y.\textit{play}'xy$$

These are structural functions. They determine the tree on the left.

But now we have BOTH syntax and semantics IN A CATEGORY, because they are functionally determined.

$$\begin{array}{lcl} \mathtt{S} & \rightarrow & \mathtt{NP}\ \ \mathtt{VP} \\ \mathtt{VP} & \rightarrow & \mathtt{V}_{tv}\ \ \mathtt{NP} \\ \mathtt{V}_{tv} & \rightarrow & \text{played} \end{array}$$

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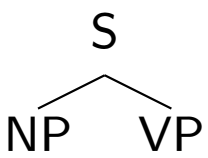

If the subject is ALSO unique in the main clause, why not start with the subject?

$\mathtt{NP} = \mathtt{S}/\mathtt{VP} = \mathtt{S}/(\mathtt{S}\backslash\mathtt{NP})$

$$\textit{Ayşe} = \mathtt{S}/(\mathtt{S}\backslash\mathtt{NP}) : \lambda p.p\ \textit{ayse}'$$

Now the predicate is OPAQUE (p). On what basis are we going to choose a category?

This asymmetry is the somewhat neglected discovery of Richard Montague.

- A clause can take many different kinds of constituents with varying categories.

- But one determines what it means to be a clause: The verb

- Since the verb is a predicative element, it can determine the predicate-argument structure (PAS) of the clause.

PAS: Reference Choice for events: Placeholders *then* fill in truth-conditional meanings.

(2) a. played = $(\mathtt{S}\backslash\mathtt{NP})/\mathtt{NP} : \lambda x\lambda y.\mathit{play}'\,xy$
b. played = $(\mathtt{S}\backslash\mathtt{NP})/\mathtt{PP}_{\mathrm{schdl}}/\mathtt{NP}_{\mathrm{score}} : \lambda y\lambda x\lambda z.\mathit{perform}'\,(\mathit{iter}'\,x\,(\mathit{play}'\,yz))z$

- Without that kind of meaning, it is difficult with categories to study grammaticality AND the consequent sense of meaningfulness.

What must syntactic categories do?

- Assemble the PAS as syntactic structure is built.

- Syntax is still autonomous. But now it carries a baggage. The treasure is in the baggage.

- If we don't transmit both structures as we analyze, we would need independent solutions to grammaticality and meaningfulness.

- THAT is not very congenial to modeling. Real data shows why.

Syntactic decomposition does not necessarily mean semantic decomposition. It is verb-controlled.

(3) a. Zhāngsān shēng qì le
Zhangsan generate air asp
'Zhangsan got angry.' Chinese; Kao 2024:1

b. Zhāngsān shēng le hǎodà de qì
Zhangsan generate asp huge nom air
'Zhangsan got very angry.' (lit. 'Zhangsan generated huge air.')

c. Zhāngsān shēng wán qì le
Zhangsan generate finish air asp
'Zhangsan stop being angry.' (lit. 'Zhangsan finished generating air.')

Semantic idiomaticity does not mean syntactic inertness. That too is verb-sense-controlled.

(4) a. Wǒ yōu le Zhāngsān yí mò
I ASP Z one
'I teased Zhāngsān.'

b. *Wǒ yōu (le) yí mò Zhāngsān
c. *Wǒ yōumò (le) Zhāngsān

To mean 'tease', there has to be an object in between (a–b), light or heavy. Together the verb is not transitive (c).

When we make a category choice, i.e. choice of event reference, we also lay out under what conditions we see grammaticality.

(5) a. She played the piano for an hour/*in an hour.
b. She played the sonata *for an hour/in an hour.
c. She played the sonata for a year.
d. She played the piano in a year.
e. She played the piano in an hour.

(6) a–b. played = $(\mathtt{S}\backslash\mathtt{NP})/\mathtt{NP} : \lambda x\lambda y.\mathit{play}'\,xy$
c. played = $(\mathtt{S}\backslash\mathtt{NP})/\mathtt{PP}_{\mathrm{schdl}}/\mathtt{NP}_{\mathrm{score}} : \lambda y\lambda x\lambda z.\mathit{perform}'(\mathit{iter}'\,x(\mathit{play}'\,yz))z$
d–e. played = $(\mathtt{S}\backslash\mathtt{NP})/\mathtt{PP}_{\mathrm{duration}}/\mathtt{NP}_{\mathrm{tool}} : \lambda y\lambda x\lambda z.\mathit{practice}'(\mathit{iter}'\,x(\mathit{play}'\,yz))z$

Case (e) is not a whole lot different than searching for meaningfulness for the Chomsky example:

Colorless green ideas sleep furiously.

Roman Jakobson's take: "If someone's hatred never slept, why then, cannot someone's ideas fall into sleep?"

$$\text{sleep} = \mathtt{S\backslash NP} : \lambda x.\mathit{torpid}'\ x$$

Yue Ren Chao's take:

$$\text{sleep furiously} = \mathtt{S\backslash NP} : \lambda x.\text{sleep-on-idea}'\ x$$

- If syntax-semantics is so dependent on the verb,

  and verbs tend to be very choosy about the roles of arguments,

- can we address GENERAL problems of syntax-semantics with this way of thinking?

I suggested in (2025) that we can, for example, CASE:

(7) a. Mary would *to run/*runs/run.
    b. Mary wants *run/*runs/to run.
    c. Mary *run/*to run/runs.

Grammaticality vs. number of readings

(8) a. Her çocuk araba-ya bin-di. Turkish
every child-DAT board-PAST
'Every child got in the car.'
b. Araba-ya her çocuk bin-di.

How many cars?

How many in Arabaya her çocuk bindi?

Should grammar say something about the number of readings?

- If we want our grammars to take care of grammaticality and the consequent sense of meaningfulness, we must start with the verb.

  - That's where the choices of event reference and meaning are.

- Leaving all that to implicature, pragmatics or discourse would not explain narrow behavior.

  - Sandra (1998) warned us about the two extremes (one lexical entry serves all, all senses served by different entries).

- Without narrow behavior, scientific modeling is hopeless.

- Without an independently replicable path to go from theory of grammar to models of grammar, a 'theory' would not be a natural science theory.

The knowledge of grammar must be representable.

- Category choice is an intentional (and intensional) act.
- Only subjects do that; models or computers don't.
- Sapir 1949:17–18 called it shared psychological spaces.
- He didn't call it shared psychological states.
- We are talking about social semiotics, not psychology.

- We may not be at the mercy of our psychological or biological make-up for categories. At least Schopenhauer (1819); Ryle (1937) didn't think so.

- To understand the role of choice in linguistic analysis, we must worry about how and where the relevant knowledge goes in the grammar.

- Unfortunately, it does not mean we can express all that can be imagined.

  - There are GAPS in the linguistic data.

  - That is why linguistics is a natural science.

- It is hard to study common timeframe of language acquisition without such gaps.

- There seems to be invariants in the structuring of grammaticality and the consequent sense of meaningfulness (e.g. compositionality).

- These invariants may spell the landscape of the variants.

- Cross-linguistic and intra-linguistic typology.

- We may discover new ideas to go in to any grammar to explore these aspects.

- Mathematics is the time-honored study of invariants.
- If we do not constrain the space of the variants, we would be in the dark about the sufficiency of supposedly necessary mechanisms.

In short:

There seems to be a limit about the space of possible human linguistic categories. Understanding the limit means understanding ourselves.

- Not quite minimally, all and only the knowledge that affects grammaticality and the consequent sense of meaningfulness (not necessarily sensefulness), enters any grammar.
- That doesn't sound to me like everything under the sun.
- Natural Grammars must be modelable, as a consequence of a theory of grammar.
- A scientific model prepares a theory or an idea for experiments.
- For that we need an explicit nomenclature and modeling vocabulary.

  -Either we make everything under the sun testable this way,

  -Or we narrow the knowledge scope of possible NL grammars so that we can do this.

Teşekkürler

Thank you

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