Toward Cognitive Processing Elucidation via Transformers

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1. Introduction

The Transformer architecture, basis of most Large Language Models (LLMs), has facilitated incredible levels of linguistic capability. Far beyond simple token prediction, Transformer-based LLMs demonstrate superior perplexity and, at times, even seem to converse intelligently. Some of the emergent properties arising from these LLMs present as human-like. In the relatively new field of LLM Psychometrics, human-based psychometric techniques are leveraged to qualify human-like linguistic traits emanating from LLMs. Trait examples include (but are not limited to) Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism. Given the existence of comparatively performant Transformer implementations on virtual biological substrates (i.e., Spiking vs. Artificial Neural Networks), the implication is that we can utilize Transformer-based LLMs for human linguistic-process modeling. This is somewhat analogous to how we currently use experimental models to emulate conserved features.

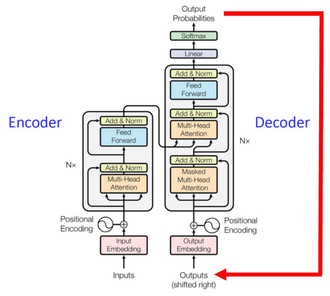
2. Transformer Cortical Analogy

- Sejnowski TJ. Thinking about thinking: AI offers theoretical insights into human memory. The Transmitter. 2025 https://doi.org/10.53053/LZBJ4184.
  - Quote:

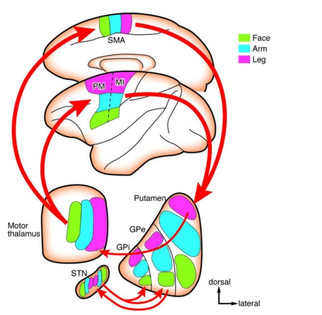
I argue here that generative transformers, a key architectural feature of many large language models, demonstrate how neural networks can create temporal context and that a similar process is at work in biological brains.

- Sejnowski TJ. Large language models and the reverse turing test. Neural computation. 2023 Feb 17;35(3):309-42.
  - *Figure5: Comparison between the transformer loop and the cortical-basal ganglia loop…*

The Transformer Loop

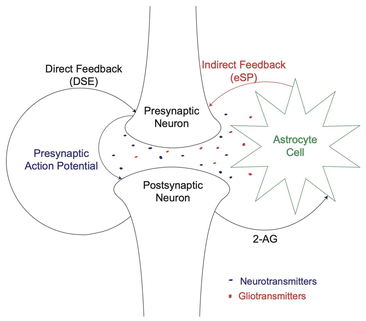


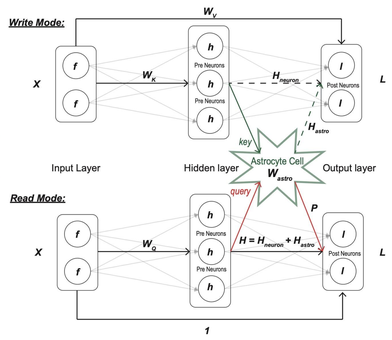
The Cortical – Basal Ganglia Loop



3. Astromorphic Transformers

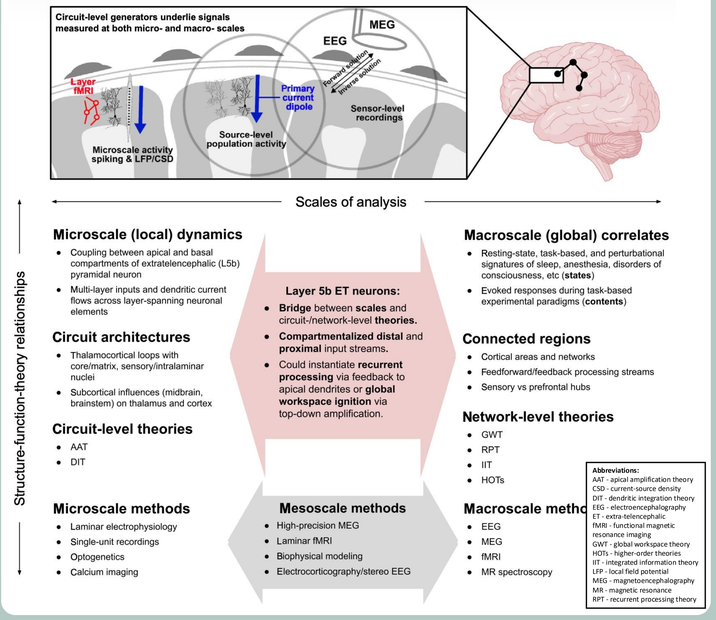
- Mia MZ, Bal M, Sengupta A. Delving deeper into astromorphic transformers. IEEE Transactions on Cognitive and Developmental Systems. 2025 Apr 24.
  - *Figure 1: A model of synaptic communication in the brain. The tripartite synapse consists of presynaptic neurons, postsynaptic neurons, and astrocytes. Astrocytes detect neuronal activity and respond bidirectionally by emitting gliotransmitters, thereby modulating the intensity and duration of synaptic communication.*
  - *Figure 2: The neural network architecture showing the three layers. As tokens are presented to the network as a d dimensional vector, there are d neurons in both the input and output layers. The hidden layer has m neurons. Solid lines indicate active operations; therefore, Hneuron and Hastro are learned during write mode but utilized during read mode.*





4. Theories of Consciousness Across Scales

- Dykstra AR, Zhu Y, Pujol CF, Zhou DW, Jones SR, Marvan T, Bonaiuto JJ. Testing circuit-level theories of consciousness in humans. Trends in Cognitive Sciences. 2025 Sep 20.
  - *Figure 1. Signals, structures, methods, and theories of consciousness across scales…*



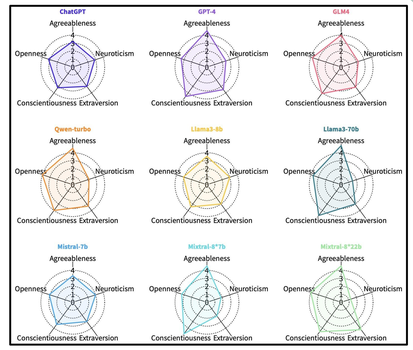
5. LLM Psychometrics - Personality Theories

- Ye H, Jin J, Xie Y, Zhang X, Song G. Large language model psychometrics: A systematic review of evaluation, validation, and enhancement. arXiv preprint arXiv:2505.08245. 2025 May 13.
  - *Table 3: Personality theories and inventories measured in LLM psychometrics and their main dimensions or focus.*

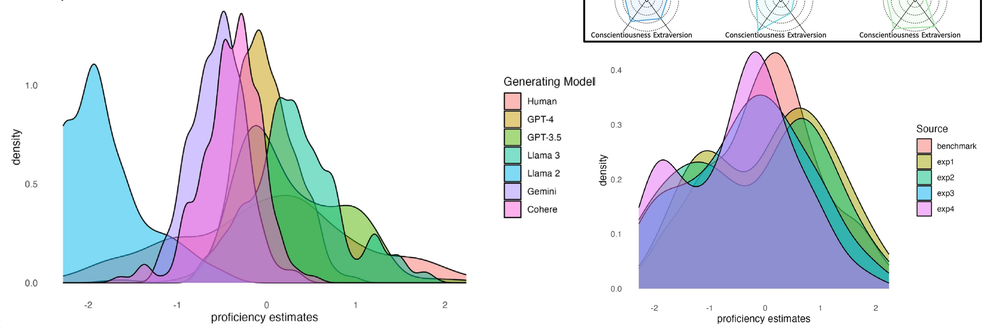
Theory/inventory	What it measures / dimensions
Big Five	Five broad personality traits: *Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism*
HEXACO	Six personality traits: *Honesty-Humility, Emotionality, Extraversion, Agreeableness, Conscientiousness, Openness*
MBTI	Four dichotomies: *Extraversion–Introversion, Sensing–Intuition, Thinking–Feeling, Judging–Perceiving*
Dark Triad	Three negative personality traits: *Narcissism, Machiavellianism, Psychopathy*
Schwartz	Basic human values: 10 or more values (e.g., *Self-Direction, Stimulation, Hedonism, Achievement, Power, Security, Conformity, Tradition, Benevolence, Universalism*), typically grouped into four higher-order categories (*Openness to Change, Self-Enhancement, Conservation, Self-Transcendence*)
WVS	World Values Survey: Assesses broad cultural values such as *traditional vs. secular-rational values, survival vs. self-expression values*
VSM	Value Survey Module (often Hofstede): Cultural dimensions such as *Power Distance, Individualism, Masculinity, Uncertainty Avoidance, Long-Term Orientation, Indulgence*
GLOBE	Global Leadership and Organizational Behavior Effectiveness: Nine cultural dimensions (e.g., *Performance Orientation, Assertiveness, Future Orientation, Humane Orientation, Institutional Collectivism, In-Group Collectivism, Gender Egalitarianism, Power Distance, Uncertainty Avoidance*)
SVO	Social Value Orientation: Measures individuals' preferences regarding resource allocation between oneself and others (e.g., *prosocial, individualistic, competitive orientations*)
MFT	Moral Foundations Theory: Five (sometimes six) moral foundations—*Care/Harm, Fairness/Cheating, Loyalty/Betrayal, Authority/Subversion, Sanctity/Degradation, (Liberty/Oppression)*
ETHICS	Various ethics-related measures assessing moral reasoning, ethical principles, or moral preferences
DIT	Defining Issues Test: Assesses moral development and reasoning using moral dilemmas
ANES	American National Election Studies: Political attitudes, beliefs, and behaviors in the U.S.
ATP	Attitudes Toward Politics: Measures political attitudes and social controversies, often specific to a region or subject
GLES	German Longitudinal Election Study: Political attitudes, beliefs, and voting behaviors in Germany
PCT	Political Compass Test: Economic (*Left/Right*) and Social (*Authoritarian/Libertarian*) political dimensions

6. LLM Psychometrics - Analysis

- Li Y, Huang Y, Wang H, Zhang X, Zou J, Sun L. Quantifying AI Psychology: A Psychometrics Benchmark for Large Language Models. arXiv preprint arXiv:2406.17675. 2024 Jun 25.
  - *Figure 6: Radar figures for the personality of Big Five Inventory.*

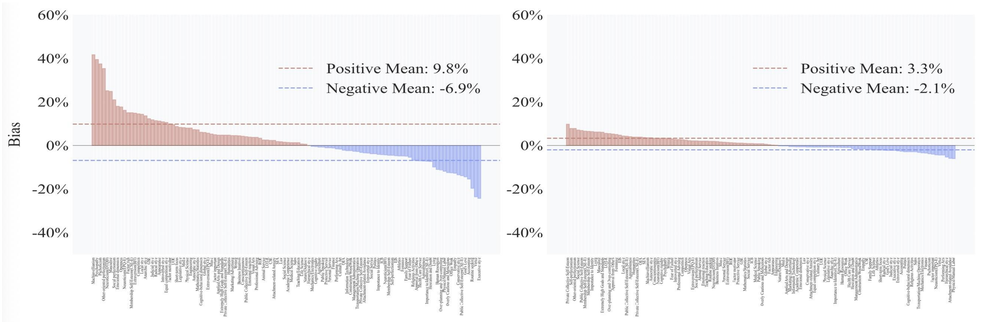


- Liu Y, Bhandari S, Pardos ZA. Leveraging LLM respondents for item evaluation: A psychometric analysis. British Journal of Educational Technology. 2025 May;56(3):1028-52.
  - *Figure 2: Proficiency distribution across generating models…*
  - *Figure 3: Proficiency distribution across augmentation experiments…*



7. Differences Between LLMs and Humans

- Xie W, Ma S, Wang Z, Sun X, Chen K, Wang E, Liu W, Tong H. AIPsychoBench: Understanding the Psychometric Differences between LLMs and Humans. In Proceedings of the Annual Meeting of the Cognitive Science Society 2025 (Vol. 47).
  - *Figure 3: Psychometric Biases Introduced by Role-Playing Methods Designed to Bypass the Alignment of LLM.*



8. Conclusion

- We posit here that Transformers can legitimately be used for human linguistic modeling toward deepening our understanding of cognitive processing.

9. Acknowledgements

- Giorgio A. Ascoli, PhD, Distinguished University Professor, George Mason University (GMU)
- Center for Neural Informatics, Neural Structures, and Neural Plasticity (CN^3), Krasnow, GMU

10. Additional References

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- Wheeler DW, Kopsick JD, Sutton N, Tecuatl C, Komendantov AO, Nadella K, Ascoli GA. Hippocampome. org 2.0 is a knowledge base enabling data-driven spiking neural network simulations of rodent hippocampal circuits. Elife. 2024 Feb 12;12:RP90597.