R. Thomas McCoy

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RESEARCH INTERESTS

I study computational linguistics using techniques from cognitive science, machine learning, and natural language processing. My research focuses on how to achieve robust generalization in models of language, as this remains one of the main areas where current AI systems fall short and one of the most impressive components of language processing in humans. In particular, I study which **inductive biases** and which **representations of structure** enable robust generalization, since these are two of the major components that determine how learners generalize to novel types of input. Underlying much of this work is an additional theme of **analyzing and interpreting** neural network models.

EDUCATION

2017–present	Johns Hopkins University: Ph.D. in Cognitive Science. GPA: 4.0. *Advisors:* Tal Linzen, Paul Smolensky
2013–2017	Yale University: B.A. in Linguistics, *summa cum laude*, distinction in the major. GPA: 4.0. *Advisor:* Robert Frank
Summer 2016	Institute on Collaborative Language Research (CoLang), University of Alaska Fairbanks
Summer 2015	Linguistic Summer Institute, University of Chicago

EMPLOYMENT

Summer 2020	Microsoft Research intern Supervisor: Asli Celikyilmaz *Evaluation methods for neural text generation systems*
Summer 2018	Jelinek Summer Workshop on Speech and Language Technology (JSALT) sentence representations team Team leaders: Sam Bowman, Ellie Pavlick *Analysis techniques for learned sentence representations.*

Summer 2017	Carnegie Mellon University team for the DARPA Low Resource Languages for Emergent Incidents (LORELEI) project
	Team leader: Patrick Littell
	Finite-state morphological analyzer for Oromo.

Summer 2017	Chirila project
	Supervisor: Claire Bowern
	Developed automatic semantic processing techniques for an online database of Australian languages.

Summer 2016	Grammar Boot Camp
	Supervisor: Claire Bowern
	Wrote a sketch grammar of Kuwarra.

Summer 2015	Yale Grammatical Diversity Project
	Supervisors: Laurence Horn, Jim Wood, Raffaella Zanuttini, Jason Zentz
	Edited web pages about regional grammatical phenomena.

Summer 2014	Irish lip rounding research
	Supervisor: Ryan Bennett
	Collected lip rounding measurements from images of Irish speakers.

Summer 2014	Linguistic Core Multi-University Research Initiative
	Team leaders: Chris Dyer, Lori Levin
	English-to-Malagasy tree-to-string transducer.

Summer 2013	Linguistic Core Multi-University Research Initiative
	Team leaders: Chris Dyer, Lori Levin
	Finite state morphological analyzer for Kinyarwanda.

Teaching

Spring 2020	Johns Hopkins University
	Role: Teaching Assistant
	Course: Foundations of Cognitive Science
	Lecture Instructor: Paul Smolensky
	Led one seminar discussion and graded assignments.

Fall 2019	Johns Hopkins University
	Role: Teaching Assistant, Lab Instructor
	Course: Computational Psycholinguistics
	Lecture Instructor: Tal Linzen
	Led lab sessions and graded assignments.

Spring 2019	Johns Hopkins University
	Role: Teaching Assistant
	Course: Syntax I
	Lecture Instructor: Géraldine Legendre
	Led review sessions and graded assignments.

Fall 2018	Johns Hopkins University
	Role: Teaching Assistant
	Course: Introduction to Computational Cognitive Science
	Lecture Instructor: Tal Linzen
	Created educational simulations, tutorials, and homeworks in Javascript and Jupyter and taught lectures using these resources.

Spring 2018	Johns Hopkins University
	Role: Fieldwork Instructor
	Course: World of Language
	Lecture Instructor: Géraldine Legendre
	Led two sections of weekly fieldwork sessions complementing lectures.

Summer 2015	Linguistic Society of America Summer Institute
	Role: Workshop Co-Instructor
	Course: Linguistic Enigmatography
	Co-Instructor: Lori Levin
	Developed and co-taught a one-week workshop on creating linguistic puzzles.

AWARDS

1. Fellowships

2018–2021	NSF Graduate Research Fellowship
	Project title: Assessing the capacity of computational models to make linguistic generalizations

2021	Sweitzer Fellow
	Fellowship awarded by the Johns Hopkins Department of Cognitive Science to one graduate student.

2020	Finalist: Facebook Fellowship
	One of four finalists in the Natural Language Processing category; two of the four finalists received fellowships.

2017–2020	Owen Scholars Fellowship
	Fellowship for outstanding incoming Johns Hopkins PhD students in the natural sciences.

2017	Finalist, Rhodes Scholarship

2017	Finalist, Marshall Scholarship

2. Prizes

2017	Alpheus Henry Snow Prize
	Award for the graduating Yale senior who is "adjudged by the faculty to have done the most for Yale by inspiring in his or her classmates an admiration and love for the best traditions of high scholarship."

2016   Hart Lyman Prize
        Award for the Yale junior who "has made through his/her own efforts the best
        record intellectually and socially."

2016   Phi Beta Kappa
        One of 13 Yale students admitted as juniors.

2013   World champion team at the International Linguistics Olympiad
        Member of the four-person U.S. team selected by the North American Computa-
        tional Linguistics Olympiad.

2013   United States Presidential Scholar
        One of two for Pennsylvania.

3. Grants

2019   NeurIPS Travel Grant
            Grant to fund travel to present work at the NeurIPS workshop on Context
            and Compositionality in Biological and Artificial Neural Systems.

2019   ICLR Travel Grant
            Grant to fund travel to present two projects at the 2019 ICLR conference.

2018–2019   Johns Hopkins University Center for Educational Resources Technology Fel-
            lowship Grant
            Co-Grantee: Tal Linzen
            Grant to develop interactive visualizations of concepts in computational cog-
            nitive science.

MAIN PROJECTS

See the PUBLICATIONS section below for the full references of the papers referred to here.

2018–present: Discovering the compositional structure implicitly learned by neural networks
  - Implemented several novel architectures based in the Tensor Product Representation formalism as a tool for analyzing the vector representations learned by neural network models. The goal of this analysis is to test the hypothesis that these vector representations are implicitly symbolic structures. GitHub: https://github.com/tommccoy1/tpdn
  - Analyzed the representations of models trained on synthetic string-manipulation tasks as well as state-of-the-art sentence embedding models. Published in [10] and [8]. Further results are being written up in [26].
  - Created a Javascript demo: https://rtmccoy.com/tpdn/tpr_demo.html
  - This project is the topic of my dissertation, which is ongoing.

2020–present: Evaluating novelty in neural text generation systems
  - Internship project at Microsoft Research analyzing the extent to which text generated by GPT-2, a state-of-the-art text generation system, is novel vs. copied from the training set.
  - Results and code are ready for release in [24].

2020–present: Imparting linguistic inductive biases via meta-learning
- Implemented model-agnostic meta-learning (MAML) in PyTorch and applied it to neural networks to give them learning biases based on Optimality Theory. GitHub: https://github.com/tommccoy1/meta-learning-linguistic-biases.
- Analyzed data efficiency and generalization for a model that had undergone meta-learning. Published the results in [2].
- JavaScript demo: http://rtmccoy.com/meta-learning-linguistic-biases.html

2019–present: Artificial language learning experiments testing people's syntactic generalization
- Conducted an Artificial Language Learning experiment on Mechanical Turk testing how people generalize center embedding. Published the results in [1].
- In ongoing work, we have expanded the Bayesian ideal learner model of Perfors, Tenenbaum, and Regier (2011) by enabling it to handle unification constraints. We are now using this augmented model to design additional experiments.

2017–2020: Understanding syntactic inductive biases of sequence-to-sequence recurrent neural networks
- Implemented many types of sequential and tree-based recurrent neural networks in PyTorch, including novel variations of these architectures. GitHub: https://github.com/tommccoy1/rnn-biases
- Trained models on syntactic tasks such as question formation (e.g., changing *The man is happy* into *Is the man happy?*), and analyzed how models' syntactic inductive biases are affected by model structure, hyperparameters, and training setup (e.g., single-task vs. multi-task learning).
- Published results in [3] and [6]; further results are on the project website: http://rtmccoy.com/rnn_hierarchical_biases.html.
- In work that is in preparation, we analyzed models trained on the CHILDES corpus to test which learning biases are sufficient to induce models to generalize as children do from the type of input that children receive, to be submitted as [25].

2019–present: Heuristic Analysis of NLI Systems
- Created a controlled evaluation set called Heuristic Analysis of NLI Systems (HANS) which tests how robustly models trained on natural language inference (NLI) generalize to examples outside of their training distribution. GitHub: https://github.com/tommccoy1/hans
- Evaluated 4 state-of-the-art models on the HANS dataset, revealing how even these models are overly reliant on heuristics rather than valid inference. Published in [16].
- Conducted follow-up work showing how different random restarts of BERT can have vastly differing performance on HANS. Published in [5].
- In ongoing work, we are studying data augmentation as a solution to these problems. Some of this work was published in [15].

2018: JSALT sentence representations team
- Member of a team at the Jelinek Summer Workshop on Speech and Language Technology (JSALT) studying learned sentence representations.
- Evaluated various state-of-the-art models on syntax-based tasks, and analyzed their performance on these tasks. Resulted in components of [9], [11], and [17].

PUBLICATIONS

Inductive biases in humans and machines

[1] 2021 **R. Thomas McCoy**, Jennifer Culbertson, Paul Smolensky, and Géraldine Legendre. Infinite use of finite means? Evaluating the generalization of center embedding learned from an artificial grammar. In *CogSci Conference 2021*. Poster.

[2] 2020 **R. Thomas McCoy**, Erin Grant, Paul Smolensky, Thomas L. Griffiths, and Tal Linzen. Universal linguistic inductive biases via meta-learning. In *CogSci Conference 2020*. Talk.

[3] 2020 **R. Thomas McCoy**, Robert Frank, and Tal Linzen. Does syntax need to grow on trees? Sources of hierarchical inductive bias in sequence-to-sequence networks. *TACL*. Journal article.

[4] 2020 Michael Lepori, Tal Linzen, and **R. Thomas McCoy**. Representations of Syntax [MASK] Useful: Effects of Constituency and Dependency Structure in Recursive LSTMs. *ACL*. Pre-recorded virtual talk.

[5] 2020 **R. Thomas McCoy**, Junghyun Min, and Tal Linzen. BERTs of a feather do not generalize together: Large variability in generalization across models with similar test set performance. *BlackboxNLP: Analyzing and Interpreting Neural Networks for NLP*.

[6] 2018 **R. Thomas McCoy**, Robert Frank, and Tal Linzen. Revisiting the poverty of the stimulus: hierarchical generalization without a hierarchical bias in recurrent neural networks. In *CogSci Conference 2018*.

Representations of structure

[7] 2020 Michael Lepori and **R. Thomas McCoy**. Picking BERT's brain: Analyzing contextualized embeddings using Representational Similarity Analysis. *COLING*.

[8] 2020 Paul Soulos, **R. Thomas McCoy**, Tal Linzen, and Paul Smolensky. Uncovering the compositional structure of vector representations with Role Learning Networks. *BlackboxNLP: Analyzing and Interpreting Neural Networks for NLP*.

[9] 2019 Najoung Kim, Roma Patel, Adam Poliak, Alex Wang, Patrick Xia, **R. Thomas McCoy**, Ian Tenney, Alexis Ross, Tal Linzen, Benjamin Van Durme, Samuel R. Bowman, Ellie Pavlick. Probing What Different NLP Tasks Teach Machines about Function Word Comprehension. *Proceedings of the Eighth Joint Conference on Lexical and Computational Semantics (*SEM 2019)*. Talk.
Best paper award at *SEM 2019.

[10] 2019 **R. Thomas McCoy**, Tal Linzen, Ewan Dunbar, and Paul Smolensky. RNNs implicitly implement tensor-product representations. *ICLR 2019*.

[11] 2019 Ian Tenney, Patrick Xia, Berlin Chen, Alex Wang, Adam Poliak, **R. Thomas McCoy**, Najoung Kim, Benjamin Van Durme, Samuel R. Bowman, Dipanjan Das, and Ellie Pavlick. What do you learn from context? Probing for sentence structure in contextualized word representations. *ICLR 2019*.

[12] 2017 Jungo Kasai, Robert Frank, **R. Thomas McCoy**, Owen Rambow, and Alexis Nasr. TAG parsing with neural networks and vector representations of supertags. *EMNLP 2017*.

[13] 2017 Dan Friedman*, Jungo Kasai*, **R. Thomas McCoy***, Robert Frank, Forrest Davis, and Owen Rambow. Linguistically Rich Vector Representations of Supertags for TAG Parsing. In *Proceedings of the 13th International Workshop on Tree Adjoining Grammars and Related Formalisms*. Talk. *Equal contribution.

Robust generalization

[14] 2021 Paul Soulos, Sudha Rao, Caitlin Smith, Eric Rosen, Asli Celikyilmaz, **R. Thomas McCoy**, Yichen Jiang, Coleman Haley, Roland Fernandez, Hamid Palangi, Jianfeng Gao and Paul Smolensky. Structural Biases for Improving Transformers on Translation into Morphologically Rich Languages. *LoResMT 2021*. Pre-recorded virtual talk.

[15] 2019 Junghyun Min, **R. Thomas McCoy**, Dipanjan Das, Emily Pitler, and Tal Linzen. Syntactic data augmentation increases robustness to inference heuristics. *ACL 2020*. Pre-recorded virtual talk.

[16] 2019 **R. Thomas McCoy**, Ellie Pavlick, and Tal Linzen. Right for the Wrong Reasons: Diagnosing Syntactic Heuristics in Natural Language Inference. *ACL 2019*. Talk.

[17] 2019 Samuel R. Bowman, Ellie Pavlick, Edouard Grave, Benjamin Van Durme, Alex Wang, Jan Hula, Patrick Xia, Raghavendra Pappagari, **R. Thomas McCoy**, Roma Patel, Najoung Kim, Ian Tenney, Yinghui Huang, Katherin Yu, Shuning Jin, and Berlin Chen. Can You Tell Me How to Get Past Sesame Street? Sentence-Level Pretraining Beyond Language Modeling. *ACL 2019*.

[18] 2019 **R. Thomas McCoy** and Tal Linzen. Non-entailed subsequences as a challenge for natural language inference. In *Proceedings of the Society for Computation in Linguistics (SCiL) 2019*.

Other topics

[19] 2019 **R. Thomas McCoy**. Touch *down* in Pittsburghese. *Yale Working Papers in Grammatical Diversity*. Working paper.

[20] 2018 Patrick Littell, **R. Thomas McCoy**, Na-Rae Han, Shruti Rijhwani, Zaid Sheikh, David Mortensen, Teruko Mitamura, and Lori Levin. Parser combinators for Tigrinya and Oromo morphology. In *Language Resources and Evaluation Conference (LREC) 2018.*

[21] 2018 **R. Thomas McCoy** and Robert Frank. Phonologically Informed Edit Distance Algorithms for Word Alignment with Low-Resource Languages. In *Proceedings of the Society for Computation in Linguistics (SCiL) 2018.*

[22] 2017 **R. Thomas McCoy**. English comparatives as degree-phrase relative clauses. In *Proceedings of the Linguistic Society of America 2.*

WORK IN PREPARATION

[23] Paul Smolensky, **R. Thomas McCoy**, Roland Fernandez, Matthew Goldrick, and Jianfeng Gao. The new generation of AI systems empowered by key cognitive principles. Accepted to *AI Magazine.*

[24] **R. Thomas McCoy**, Paul Smolensky, Tal Linzen, Jianfeng Gao, and Asli Celikyilmaz. How much do language models copy from their training data? Evaluating linguistic novelty in text generation. In preparation to submit to *TACL.*

[25] Aditya Yedetore, Tal Linzen, Robert Frank, and **R. Thomas McCoy**. How poor is the stimulus? Evaluating hierarchical generalization in neural networks trained on child-directed speech. In preparation to submit to *ACL.*

[26] **R. Thomas McCoy**, Tal Linzen, and Paul Smolensky. DISCOVER: A framework for dissecting compositionality in vector representations. In preparation to submit to *JAIR.*

UNPUBLISHED CONFERENCE PRESENTATIONS

2018 R. Thomas McCoy, Robert Frank, and Tal Linzen. Investigating hierarchical bias in the acquisition of English question formation with recurrent neural networks. Poster presentation, *2018 Legrain conference: Learning Language in Humans and in Machines*, Paris,France, July 5-6.

2018 Robert Frank, R. Thomas McCoy, and Tal Linzen. Neural network syntax in the age of deep learning: the case of question formation. Oral presentation, *Society for Computation in Linguistics*, Salt Lake City, Utah, January 5.

2017 Patrick Littell, R. Thomas McCoy, and Lori Levin. The North American Computational Linguistics Olympiad. Oral presentation, in Datablitz: Getting High School Students into Linguistics: Current Activities and Future Directions, *Linguistic Society of America Annual Meeting*, Austin, Texas, January 7.

INVITED TALKS

2021   Montreal Computational and Quantitative Linguistics Lab (MCQLL). October 26, 2021.
Discovering implicit compositional representations in neural networks

2021   Edinburgh Centre for Language Evolution. September 28, 2021.
How do neural networks represent compositional symbolic structure?

2021   USC ISI Natural Language Seminar. April 15, 2021.
Universal Linguistic Inductive Biases via Meta-Learning.

2020   DeepMind language reading group. December 7, 2020.
Analyzing the syntactic inductive biases of sequence-to-sequence networks.

2020   Berkeley NLP Seminar. October 16, 2020.
Analyzing the syntactic inductive biases of sequence-to-sequence networks.

2020   NLP With Friends seminar series. August 12, 2020.
Universal Linguistic Inductive Biases via Meta-Learning.

2019   Workshop on Gradient Symbolic Computation. Johns Hopkins University. September 19, 2019.
Tensor product decomposition of continuous vector representations

2018   Microsoft Research, Redmond. December 11, 2018.
Discovering the compositional structure implicitly learned by neural networks

MENTORING

Master's students

2019–2020   Junghyun Min
Co-authored [5] and [15]. Co-supervised with Tal Linzen.

2019–2020   Paul Soulos
Co-authored [8]. Co-supervised with Paul Smolensky.

Undergraduate students

2019–present   Aditya Yedetore
Ongoing research to be submitted as [25]. Co-supervised with Tal Linzen.

2019–2020   Michael Lepori
Co-authored [4] and [7]. Co-supervised with Tal Linzen.

SERVICE

2020–present	Johns Hopkins CogSci Representation and Diversity Committee. Co-created and co-organized a program for giving prospective students feedback on their PhD applications.
2016–2017	Computational Linguistics at Yale (CLAY) reading group: Co-organizer.
2015–2017	Yale Undergraduate Linguistics Society: Co-founder (2015), president (2015–2016), treasurer (2016–2017).

REVIEWING

2021	Workshop reviewer: BlackboxNLP 2021.
2021	Journal reviewer: Natural Language Engineering.
2021	Conference reviewer: EMNLP 2021.
2020	Conference reviewer: CoNLL 2020.
2020	Conference reviewer: EMNLP 2020. Recognized as an outstanding reviewer.
2020	Conference reviewer: ACL 2020.
2019	Conference reviewer: CoNLL 2019.
2018	Conference reviewer: CoNLL 2018.
2018	Conference reviewer: ACL 2018. Recognized as a top reviewer.

OUTREACH

2020	Public talk for the National Museum of Language: *Language Squared: The Linguistics of Crosswords*.
2013-present	North American Computational Linguistics Olympiad (NACLO). National level: Co-Program Chair; problem writer (16 problems to date). Local level: Co-founder and co-organizer of the Yale contest site (2013-2017); co-organizer of the Johns Hopkins contest site (2017-present); organizer of pre-contest practice sessions at both sites.
2018–2019	International Linguistics Olympiad (IOL): Problem writer.
2016	Yale Grammatical Diversity Project: Authored two webpages describing regional grammatical phenomena (*All the further* and *Subject contact relatives*).
2013–2017	Linguistics teaching initiatives: Designed and taught a one-lecture linguistics class to high school students in connection with the separate programs Splash, Sprout, and Math Mornings. Presented 8 times to groups ranging from 25 to 50 students.

PROFESSIONAL MEMBERSHIPS

2015–present	Linguistic Society of America (LSA).
2017–present	Association for Computational Linguistics (ACL).
2018–present	Cognitive Science Society.

Skills

Programming languages	Python, PyTorch, JavaScript, Haskell, C, Java, R, Scheme.
Natural languages	English (native), Bahasa Indonesia (basic conversation), Old English (basic reading ability), Old Norse (basic reading ability), Latin (basic reading ability).

Coursework

Undergraduate GPA: 4.0   *Graduate GPA:* 4.0

Computational Linguistics: Language and Computation I, Language and Computation II, Formal Foundations of Linguistic Theories, Computing Meaning

Natural Language Processing: Natural Language Processing, Machine Learning: Linguistic and Sequence Modeling

Syntax: Syntax I, Syntax II, Grammatical Diversity in US English

Phonetics/Phonology: Phonetics, Phonology I, Phonology II, The Phonetics/Phonology Interface

Semantics: Semantics I, Semantics II

Computer Science: Data Structures and Programming Techniques, Computational Tools for Data Science

Mathematics: Multivariable Calculus, Discrete Mathematics, Probability and Statistics, Advanced Statistical Methods

Other relevant courses: Linguistic Field Methods, Foundations of Cognitive Science