

## Limitations

For the API-based models used in RECONCILE, we note that we lack complete knowledge of the data that these models have been exposed to, and their scales in terms of parameters. Moreover, due to the API access, we do not possess complete control over their behavior. Depending on API-based models also necessitates the need to prompt these models to estimate their confidence. While this approach proves effective as evidenced by our results, we note that these estimates remain post-hoc in nature. Nevertheless, it is worth highlighting that these limitations could potentially be mitigated in the future should more open-sourced models emerge and demonstrate robust capabilities in adhering to long instructions.

## Acknowledgments

We thank Peter Hase, Elias Stengel-Eskin, and the anonymous reviewers for useful feedback and suggestions regarding experiments for useful feedback and suggestions regarding experiments. This work was supported by NSF-CAREER Award 1846185, NSF-AI Engage Institute DRL-2112635, DARPA MCS Grant N66001-19-2-4031, Accelerate Foundation Models Research program, and a Google PhD Fellowship. The views contained in this article are those of the authors and not of the funding agency.

## References

- Shourya Aggarwal, Divyanshu Mandowara, Vishwajeet Agrawal, Dinesh Khandelwal, Parag Singla, and Dinesh Garg. 2021. [Explanations for commonsenseqa: New dataset and models](#). In *Proceedings of the 59th Annual Meeting of the Association for Computational Linguistics and the 11th International Joint Conference on Natural Language Processing (Volume 1: Long Papers)*, pages 3050–3065.
- Rohan Anil, Andrew M. Dai, Orhan Firat, Melvin Johnson, Dmitry Lepikhin, Alexandre Passos, Siamak Shakeri, Emanuel Taropa, Paige Bailey, Zhifeng Chen, Eric Chu, Jonathan H. Clark, Laurent El Shafey, Yanping Huang, Kathy Meier-Hellstern, Gaurav Mishra, Erica Moreira, Mark Omernick, Kevin Robinson, Sebastian Ruder, Yi Tay, Kefan Xiao, Yuanzhong Xu, Yujing Zhang, Gustavo Hernandez Abrego, Junwhan Ahn, Jacob Austin, Paul Barham, Jan Botha, James Bradbury, Siddhartha Brahma, Kevin Brooks, Michele Catasta, Yong Cheng, Colin Cherry, Christopher A. Choquette-Choo, Aakanksha Chowdhery, Cl  ment Crepy, Shachi Dave, Mostafa Dehghani, Sunipa Dev, Jacob Devlin, Mark D  az, Nan Du, Ethan Dyer, Vlad Feinberg, Fangxiaoyu Feng, Vlad Fienber, Markus Freitag, Xavier Garcia, Sebastian Gehrmann, Lucas Gonzalez, Guy Gur-Ari, Steven Hand, Hadi Hashemi, Le Hou, Joshua Howland, Andrea Hu, Jeffrey Hui, Jeremy Hurwitz, Michael Isard, Abe Ittycheriah, Matthew Jagielski, Wenhao Jia, Kathleen Kenealy, Maxim Krikun, Sneha Kudugunta, Chang Lan, Katherine Lee, Benjamin Lee, Eric Li, Music Li, Wei Li, YaGuang Li, Jian Li, Hyeontaek Lim, Hanzhao Lin, Zhongtao Liu, Frederick Liu, Marcello Maggioni, Aroma Mahendru, Joshua Maynez, Vedant Misra, Maysam Moussalem, Zachary Nado, John Nham, Eric Ni, Andrew Nystrom, Alicia Parrish, Marie Pellat, Martin Polacek, Alex Polozov, Reiner Pope, Siyuan Qiao, Emily Reif, Bryan Richter, Parker Riley, Alex Castro Ros, Aurko Roy, Brennan Saeta, Rajkumar Samuel, Renee Shelby, Ambrose Slone, Daniel Smilkov, David R. So, Daniel Sohn, Simon Tokumine, Dasha Valter, Vijay Vasudevan, Kiran Vodrahalli, Xuezhi Wang, Pidong Wang, Zirui Wang, Tao Wang, John Wieting, Yuhuai Wu, Kelvin Xu, Yunhan Xu, Linting Xue, Pengcheng Yin, Jiahui Yu, Qiao Zhang, Steven Zheng, Ce Zheng, Weikang Zhou, Denny Zhou, Slav Petrov, and Yonghui Wu. 2023. [Palm 2 technical report](#).
- Anthropic. 2023. [model card and evaluations for claude models](#).
- Maciej Besta, Nils Blach, Ales Kubicek, Robert Gerstenberger, Lukas Gianinazzi, Joanna Gajda, Tomasz Lehmann, Michal Podstawski, Hubert Niewiadomski, Piotr Nyczyk, and Torsten Hoefer. 2023. [Graph of thoughts: Solving elaborate problems with large language models](#). *arXiv preprint arXiv:2308.09687*.
- Ning Bian, Xianpei Han, Le Sun, Hongyu Lin, Yaojie Lu, and Ben He. 2023. [Chatgpt is a knowledgeable but inexperienced solver: An investigation of commonsense problem in large language models](#). *arXiv preprint arXiv:2303.16421*.
- BIG-bench collaboration. 2023. [Beyond the imitation game: Quantifying and extrapolating the capabilities of language models](#). *Transactions on Machine Learning Research*.
- Chi-Min Chan, Weize Chen, Yusheng Su, Jianxuan Yu, Wei Xue, Shanghang Zhang, Jie Fu, and Zhiyuan Liu. 2023. [Chateval: Towards better llm-based evaluators through multi-agent debate](#). *arXiv preprint arXiv:2308.07201*.
- Karl Cobbe, Vineet Kosaraju, Mohammad Bavarian, Mark Chen, Heewoo Jun, Lukasz Kaiser, Matthias Plappert, Jerry Tworek, Jacob Hilton, Reiichiro Nakano, et al. 2021. [Training verifiers to solve math word problems](#). *arXiv preprint arXiv:2110.14168*.
- Nan Du, Yanping Huang, Andrew M Dai, Simon Tong, Dmitry Lepikhin, Yuanzhong Xu, Maxim Krikun, Yanqi Zhou, Adams Wei Yu, Orhan Firat, et al. 2022. [Glam: Efficient scaling of language models with mixture-of-experts](#). In *International Conference on Machine Learning*, pages 5547–5569. PMLR.

- Yilun Du, Shuang Li, Antonio Torralba, Joshua B. Tenenbaum, and Igor Mordatch. 2023. [Improving factuality and reasoning in language models through multiagent debate](#).
- Elias Stengel-Eskin and Benjamin Van Durme. 2023. [Calibrated interpretation: Confidence estimation in semantic parsing](#). In *TACL*.
- Shangbin Feng, Weijia Shi, Yike Wang, Wenxuan Ding, Vidhisha Balachandran, and Yulia Tsvetkov. 2024. [Don't hallucinate, abstain: Identifying llm knowledge gaps via multi-llm collaboration](#). *arXiv preprint arXiv:2402.00367*.
- Yao Fu, Hao Peng, Litu Ou, Ashish Sabharwal, and Tushar Khot. 2023. [Specializing smaller language models towards multi-step reasoning](#). In *ICML*.
- Mor Geva, Daniel Khashabi, Elad Segal, Tushar Khot, Dan Roth, and Jonathan Berant. 2021. [Did aristotle use a laptop? a question answering benchmark with implicit reasoning strategies](#). *Transactions of the Association for Computational Linguistics*, 9:346–361.
- Chuan Guo, Geoff Pleiss, Yu Sun, and Kilian Q Weinberger. 2017. [On calibration of modern neural networks](#). In *International conference on machine learning*, pages 1321–1330. PMLR.
- Dan Hendrycks, Collin Burns, Saurav Kadavath, Akul Arora, Steven Basart, Eric Tang, Dawn Song, and Jacob Steinhardt. 2021. [Measuring mathematical problem solving with the math dataset](#). *NeurIPS*.
- Namgyu Ho, Laura Schmid, and Se-Young Yun. 2023. [Large language models are reasoning teachers](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 14852–14882, Toronto, Canada. Association for Computational Linguistics.
- Jie Huang, Xinyun Chen, Swaroop Mishra, Huaixiu Steven Zheng, Adams Wei Yu, Xinying Song, and Denny Zhou. 2023. [Large language models cannot self-correct reasoning yet](#). *arXiv preprint arXiv:2310.01798*.
- Robert A Jacobs, Michael I Jordan, Steven J Nowlan, and Geoffrey E Hinton. 1991. [Adaptive mixtures of local experts](#). *Neural computation*, 3(1):79–87.
- Dongfu Jiang, Xiang Ren, and Bill Yuchen Lin. 2023. [LLM-blender: Ensembling large language models with pairwise ranking and generative fusion](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 14165–14178, Toronto, Canada. Association for Computational Linguistics.
- Akbir Khan, John Hughes, Dan Valentine, Laura Ruis, Kshitij Sachan, Ansh Radhakrishnan, Edward Grefenstette, Samuel R. Bowman, Tim Rocktäschel, and Ethan Perez. 2024. [Debating with more persuasive llms leads to more truthful answers](#). *arXiv preprint arXiv:2402.06782*.
- Takeshi Kojima, Shixiang Shane Gu, Machel Reid, Yutaka Matsuo, and Yusuke Iwasawa. 2022. [Large language models are zero-shot reasoners](#). *Advances in neural information processing systems*, 35:22199–22213.
- Aitor Lewkowycz, Anders Andreassen, David Dohan, Ethan Dyer, Henryk Michalewski, Vinay Ramasesh, Ambrose Slone, Cem Anil, Imanol Schlag, Theo Gutman-Solo, et al. 2022. [Solving quantitative reasoning problems with language models](#). *Advances in Neural Information Processing Systems*, 35:3843–3857.
- Guohao Li, Hasan Abed Al Kader Hammoud, Hani Itani, Dmitrii Khizbullin, and Bernard Ghanem. 2023a. [Camel: Communicative agents for "mind" exploration of large scale language model society](#). *arXiv preprint arXiv:2303.17760*.
- Shuang Li, Yilun Du, Joshua B Tenenbaum, Antonio Torralba, and Igor Mordatch. 2022a. [Composing ensembles of pre-trained models via iterative consensus](#). *International Conference on Learning Representations (ICLR)*.
- Yanhong Li, Gang Kou, Guangxu Li, and Yi Peng. 2022b. [Consensus reaching process in large-scale group decision making based on bounded confidence and social network](#). *European Journal of Operational Research*, 303(2):790–802.
- Yifei Li, Zeqi Lin, Shizhuo Zhang, Qiang Fu, Bei Chen, Jian-Guang Lou, and Weizhu Chen. 2023b. [Making language models better reasoners with step-aware verifier](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 5315–5333, Toronto, Canada. Association for Computational Linguistics.
- Tian Liang, Zhiwei He, Wenxiang Jiao, Xing Wang, Yan Wang, Rui Wang, Yujiu Yang, Zhaopeng Tu, and Shuming Shi. 2023. [Encouraging divergent thinking in large language models through multi-agent debate](#).
- Wang Ling, Dani Yogatama, Chris Dyer, and Phil Blunsom. 2017. [Program induction by rationale generation: Learning to solve and explain algebraic word problems](#). *ACL*.
- Haipeng Luo, Qingfeng Sun, Can Xu, Pu Zhao, Jianguang Lou, Chongyang Tao, Xiubo Geng, Qingwei Lin, Shifeng Chen, and Dongmei Zhang. 2023. [Wizardmath: Empowering mathematical reasoning for large language models via reinforced evol-instruct](#). *arXiv preprint arXiv:2308.09583*.
- Aman Madaan, Niket Tandon, Prakhar Gupta, Skyler Hallinan, Luyu Gao, Sarah Wiegrefe, Uri Alon, Nouha Dziri, Shrimai Prabhumoye, Yiming Yang, Shashank Gupta, Bodhisattwa Prasad Majumder, Katherine Hermann, Sean Welleck, Amir Yazdanbakhsh, and Peter Clark. 2023. [Self-refine: Iterative refinement with self-feedback](#).

- Lucie Charlotte Magister, Jonathan Mallinson, Jakub Adamek, Eric Malmi, and Aliaksei Severyn. 2023. [Teaching small language models to reason](#). In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 2: Short Papers)*, pages 1773–1781, Toronto, Canada. Association for Computational Linguistics.
- Sabrina J. Mielke, Arthur Szlam, Emily Dinan, and Y-Lan Boureau. 2022. [Reducing conversational agents’ overconfidence through linguistic calibration](#). *Transactions of the Association for Computational Linguistics*, 10:857–872.
- Marvin Minsky. 1988. *Society Of Mind*. Simon and Schuster.
- Subhabrata Mukherjee, Arindam Mitra, Ganesh Jawahar, Sahaj Agarwal, Hamid Palangi, and Ahmed Awadallah. 2023. [Orca: Progressive learning from complex explanation traces of gpt-4](#). *arXiv preprint arXiv:2306.02707*.
- Mahdi Pakdaman Naeini, Gregory Cooper, and Milos Hauskrecht. 2015. [Obtaining well calibrated probabilities using bayesian binning](#). In *Proceedings of the AAAI conference on artificial intelligence*, volume 29.
- Yixin Nie, Adina Williams, Emily Dinan, Mohit Bansal, Jason Weston, and Douwe Kiela. 2020. [Adversarial NLI: A new benchmark for natural language understanding](#). In *Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics*, pages 4885–4901, Online. Association for Computational Linguistics.
- Maxwell Nye, Anders Johan Andreassen, Guy Gur-Ari, Henryk Michalewski, Jacob Austin, David Bieber, David Dohan, Aitor Lewkowycz, Maarten Bosma, David Luan, et al. 2021. [Show your work: Scratchpads for intermediate computation with language models](#). *arXiv preprint arXiv:2112.00114*.
- OpenAI. 2022. [Chatgpt: Optimizing language models for dialogue](#).
- OpenAI. 2023. [Gpt-4 technical report](#).
- Joon Sung Park, Joseph C. O’Brien, Carrie J. Cai, Meredith Ringel Morris, Percy Liang, and Michael S. Bernstein. 2023. [Generative agents: Interactive simulacra of human behavior](#). *arXiv preprint arXiv:2304.03442*.
- John Platt et al. 1999. Probabilistic outputs for support vector machines and comparisons to regularized likelihood methods. *Advances in large margin classifiers*, 10(3):61–74.
- Omer Sagi and Lior Rokach. 2018. [Ensemble learning: A survey](#). *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 8(4):e1249.
- Swarnadeep Saha, Peter Hase, and Mohit Bansal. 2023. [Can language models teach weaker agents? teacher explanations improve students via theory of mind](#). In *NeurIPS*.
- Timo Schick, Jane Dwivedi-Yu, Zhengbao Jiang, Fabio Petroni, Patrick Lewis, Gautier Izacard, Qingfei You, Christoforos Nalmpantis, Edouard Grave, and Sebastian Riedel. 2022. [Peer: A collaborative language model](#). *arXiv preprint arXiv:2208.11663*.
- Zhihong Shao, Peiyi Wang, Runxin Xu, Qihao Zhu, Junxiao Song, Mingchuan Zhang, Y.K. Li, Y. Wu, and Daya Guo. 2024. [Deepseekmath: Pushing the limits of mathematical reasoning in open language models](#).
- Noam Shazeer, \*Azalia Mirhoseini, \*Krzysztof Maziarz, Andy Davis, Quoc Le, Geoffrey Hinton, and Jeff Dean. 2017. [Outrageously large neural networks: The sparsely-gated mixture-of-experts layer](#). In *International Conference on Learning Representations*.
- Noah Shinn, Federico Cassano, Beck Labash, Ashwin Gopinath, Karthik Narasimhan, and Shunyu Yao. 2023. [Reflexion: Language agents with verbal reinforcement learning](#).
- Theodore R. Sumers, Shunyu Yao, Karthik Narasimhan, and Thomas L. Griffiths. 2023. [Cognitive architectures for language agents](#). *arXiv preprint arXiv:2309.02427*.
- Alon Talmor, Jonathan Herzig, Nicholas Lourie, and Jonathan Berant. 2019. [CommonsenseQA: A question answering challenge targeting commonsense knowledge](#). In *Proceedings of the 2019 Conference of the North American Chapter of the Association for Computational Linguistics: Human Language Technologies, Volume 1 (Long and Short Papers)*, pages 4149–4158, Minneapolis, Minnesota. Association for Computational Linguistics.
- Katherine Tian, Eric Mitchell, Allan Zhou, Archit Sharma, Rafael Rafailov, Huaxiu Yao, Chelsea Finn, and Christopher D Manning. 2023. [Just ask for calibration: Strategies for eliciting calibrated confidence scores from language models fine-tuned with human feedback](#). *arXiv preprint arXiv:2305.14975*.
- Hugo Touvron, Louis Martin, Kevin Stone, Peter Albert, Amjad Almahairi, Yasmine Babaei, Nikolay Bashlykov, Soumya Batra, Prajjwal Bhargava, Shruti Bhosale, Dan Bikel, Lukas Blecher, Cristian Canton Ferrer, Moya Chen, Guillem Cucurull, David Esiobu, Jude Fernandes, Jeremy Fu, Wenyin Fu, Brian Fuller, Cynthia Gao, Vedanuj Goswami, Naman Goyal, Anthony Hartshorn, Saghar Hosseini, Rui Hou, Hakan Inan, Marcin Kardas, Viktor Kerkez, Madian Khabsa, Isabel Kloumann, Artem Korenev, Punit Singh Koura, Marie-Anne Lachaux, Thibaut Lavril, Jenya Lee, Diana Liskovich, Yinghai Lu, Yuning Mao, Xavier Martinet, Todor Mihaylov, Pushkar Mishra, Igor Molybog, Yixin Nie, Andrew Poulton, Jeremy Reizenstein, Rashi Rungta, Kalyan Saladi, Alan Schelten, Ruan Silva, Eric Michael Smith, Ranjan Subramanian, Xiaoqing Ellen Tan, Binh Tang, Ross Taylor, Adina Williams, Jian Xiang Kuan, Puxin Xu, Zheng Yan, Iliyan Zarov, Yuchen Zhang, Angela Fan,