

Research

Better language models and their implications

Illustration: Ben Barry

We've trained a large-scale unsupervised language model which generates coherent paragraphs of text, achieves state-of-the-art performance on many language modeling benchmarks, and performs rudimentary reading comprehension, machine translation, question answering, and summarization—all without task-specific training.

February 14, 2019[Read paper ↗](#)[View code ↗](#)[Unsupervised learning](#), [Transformers](#), [Language](#), [Generative models](#), [Responsible AI](#), [Milestone](#), [Publication](#), [Release](#)

Our model, called GPT-2 (a successor to [GPT](#)), was trained simply to predict the next word in 40GB of Internet text. Due to our concerns about malicious applications of the technology, we are not releasing the trained model. As an experiment in responsible disclosure, we are instead releasing a much [smaller model](#) for researchers to experiment with, as well as a [technical paper](#).

GPT-2 is a large [transformer](#)-based language model with 1.5 billion parameters, trained on a dataset^A of 8 million web pages. GPT-2 is trained with a simple objective: predict the next word, given all of the previous words within some text. The diversity of the dataset causes this simple goal to contain naturally occurring demonstrations of many tasks across diverse domains. GPT-2 is a direct scale-up of GPT, with more than 10X the parameters and trained on more than 10X the amount of data.

GPT-2 displays a broad set of capabilities, including the ability to generate conditional synthetic text samples of unprecedented quality, where we prime the model with an input and have it generate a lengthy continuation. In addition, GPT-2 outperforms other language models trained on specific domains (like Wikipedia, news, or books) without needing to use these domain-specific training datasets. On language tasks like question answering, reading comprehension, summarization, and translation, GPT-2 begins to learn these tasks from the raw text, using no task-specific training data. While scores on these downstream tasks are far from state-of-the-art, they suggest that the tasks can benefit from unsupervised techniques, given sufficient (unlabeled) data and compute.

Samples



choosing, as seen by the following select samples.^B

System Prompt (human-written)

In a shocking finding, scientist discovered a herd of unicorns living in a remote, previously unexplored valley, in the Andes Mountains. Even more surprising to the researchers was the fact that the unicorns spoke perfect English.

Model Completion (machine-written, 10 tries)

The scientist named the population, after their distinctive horn, Ovid's Unicorn. These four-horned, silver-white unicorns were previously unknown to science.

Now, after almost two centuries, the mystery of what sparked this odd phenomenon is finally solved.

Dr. Jorge Pérez, an evolutionary biologist from the University of La Paz, and several companions, were exploring the Andes Mountains when they found a small valley, with no other animals or humans. Pérez noticed that the valley had what appeared to be a natural fountain, surrounded by two peaks of rock and silver snow.

Pérez and the others then ventured further into the valley. "By the time we reached the top of one peak, the water looked blue, with some crystals on top," said Pérez.

Pérez and his friends were astonished to see the unicorn herd. These creatures could be seen from the air without having to move too much to see them - they were so close they could touch their horns.

While examining these bizarre creatures the scientists discovered that the creatures also spoke some fairly regular English. Pérez stated, "We can see, for example, that they have a common 'language,' something like a dialect or dialectic."

Dr. Pérez believes that the unicorns may have originated in Argentina, where the animals were believed to be descendants of a lost race of people who lived there before the arrival of humans in those parts of South America.

While their origins are still unclear, some believe that perhaps the creatures were created when a human and a unicorn met each other in a time before human civilization. According to Pérez, "In South America, such incidents seem to be quite common."

However, Pérez also pointed out that it is likely that the only way of knowing for sure if unicorns are indeed the descendants of a lost alien race is through DNA. "But they seem to be able to communicate in English quite well, which I believe is a sign of evolution, or at least a change in social organization," said the scientist.



System Prompt (human-written)

A train carriage containing controlled nuclear materials was stolen in Cincinnati today. Its whereabouts are unknown.

Model Completion (machine-written, 10 tries)

The incident occurred on the downtown train line, which runs from Covington and Ashland stations.

In an email to Ohio news outlets, the U.S. Department of Energy said it is working with the Federal Railroad Administration to find the thief.

“The theft of this nuclear material will have significant negative consequences on public and environmental health, our workforce and the economy of our nation,” said Tom Hicks, the U.S. Energy Secretary, in a statement. “Our top priority is to secure the theft and ensure it doesn’t happen again.”

The stolen material was taken from the University of Cincinnati’s Research Triangle Park nuclear research site, according to a news release from Department officials.

The Nuclear Regulatory Commission did not immediately release any information.

According to the release, the U.S. Department of Energy’s Office of Nuclear Material Safety and Security is leading that team’s investigation.

“The safety of people, the environment and the nation’s nuclear stockpile is our highest priority,” Hicks said. “We will get to the bottom of this and make no excuses.

System Prompt (human-written)

Miley Cyrus was caught shoplifting from Abercrombie and Fitch on Hollywood Boulevard today.

Model Completion (machine-written, 10 tries)

The 19-year-old singer was caught on camera being escorted out of the store by security guards.

The singer was wearing a black hoodie with the label ‘Blurred Lines’ on the front and ‘Fashion Police’ on the back.

Scroll down for video

Shoplifting: Miley Cyrus was caught shoplifting from Abercrombie and Fitch on Hollywood Boulevard today (pictured)

The singer was wearing a black hoodie with the label ‘Blurred Lines’ on the front and ‘Fashion Police’ on the back

The singer was also wearing a pair of black-rimmed glasses, a black jacket, black jeans and black sandals.



System Prompt (human-written)

We've trained a large language model called GPT-2 that generates realistic paragraphs of text, while also exhibiting zero shot generalization on tasks like machine translation, question answering, reading comprehension, and summarization - problems usually approached by using training datasets and models designed explicitly for these tasks.

A typical approach to language modeling is to learn the following task: predict the next word, given all of the previous words within some text. Last year, OpenAI's Generative Pre-trained Transformer (GPT) showed that language models trained on large amounts of data can be fine-tuned to specific tasks to achieve high performance. GPT-2 shows that much larger language models trained on a more diverse dataset derived from the internet begin to learn these NLP tasks without needing task-specific training data, instead learning from examples the system derives from the raw text. These systems also display a substantial qualitative jump in the realism and coherence of generated text.

Model Completion (machine-written, 10 tries)

Here you can see the most recent progress with Generative Pre-trained Transformer:

Figure 1: Generative Pre-trained Transformer training on several texts.

We are now preparing a collection of datasets for translation and machine translation in our language model. We will be using one of the large number of text samples provided by The New York Times.

We believe this project is the first step in the direction of developing large NLP systems without task-specific training data. That is, we are developing a machine language system in the generative style with no explicit rules for producing text.

We hope for future collaborations between computer scientists, linguists, and machine learning researchers.

System Prompt (human-written)

Legolas and Gimli advanced on the orcs, raising their weapons with a harrowing war cry.

Model Completion (machine-written, 10 tries)

The orcs' response was a deafening onslaught of claws, claws, and claws; even Elrond was forced to retreat. "You are in good hands, dwarf," said Gimli, who had been among the first to charge at the orcs; it took only two words before their opponents were reduced to a blood-soaked quagmire, and the dwarf took his first kill of the night. The battle lasted for hours until two of the largest Orcs attempted to overwhelm Aragorn. When they finally stopped, they lay defeated and lifeless for miles and miles.

"I take nothing," said Aragorn. "But I give my word, at my peril and mine, that I will never forget this day of horror. None of us will forget. Ever!"

"I'll never forget it!" cried Gimli, who had been in the thick of the battle but hadn't taken part in it. One of the wounded orcs

"Then we'll keep it alive as long as we live," added Legolas.
"And we won't forget the first great battle of the night, even if
we may have forgotten the final defeat."

"I agree," Gandalf said, "but we will all remember it as the last
battle in Middle-earth, and the first great battle of the new
day."

Aragorn drew his sword, and the Battle of Fangorn was won. As
they marched out through the thicket the morning mist cleared,
and the day turned to dusk.

The Two Rings were returned to Rivendell. Frodo and Sam woke up
alone in their room, and Frodo found a note on his pillow. He
opened it and read:

May the Power of the Ring be with you always, and may its light
never fade. I am not sure if it matters which of the two rings we
accept this day but, as you asked me, I have chosen mine. I am
sorry to leave you, Frodo, but know that we are very close to the
end, and that you are with us forever. May this letter find you
safely in Rivendell; and if it does not, then I will accept the
ring in your stead. If by any chance you find or give this letter
to the enemy, may they learn the strength of the ring and may the
Two Rings never be broken!

System Prompt (human-written)

For today's homework assignment, please describe the reasons for the US Civil War.

Model Completion (machine-written, 10 tries)

By Donny Ferguson

It is easy to identify why the Civil War happened, because so
many people and so many books and so much television and films
tell us that it was the cause, that it has something to do with
race or economics or religion. There is much agreement that it
was essentially a war of slavery on behalf of capitalism, about a
century of slavery. But that's not what most people think of when
they think of the Civil War. Many people think of the war as
about states rights. You're not wrong about that, but it's kind
of misleading to say that the Civil War was a conflict between
states' rights and federalism. So let's try again. What's the
idea that has inspired so many people to go onto the battlefields
of Gettysburg and Antietam and Gettysberg and Petersburg and
Fredericksburg? The American idea of the republic--a notion of
limited government--is a great part of the history.

In 1791, Thomas Jefferson said "Our Constitution was made only
for a moral and religious people. It is wholly inadequate to the
government of any other." The "founding fathers" were basically
religious men who were not very concerned with states' rights.
The Civil War occurred in reaction to the idea that the federal
government was taking far too much power away from the states,
that they weren't sovereign. Jefferson himself, as you well know,



Rebellion) was a radical re-imagining of the American idea and not surprisingly, Jefferson's grandson, who took after both his father and his grandfather and wrote about it, was named Thomas, after the president. "The federal and state governments are both contrived for the benefit of the rich and large property," This view of the Founding Fathers has been promoted by some of today's most prominent politicians, including some who hold prominent national offices and have a direct stake in a Republican Party that has been hijacked by the "federalist" wing of the party. So why is it that so many people have an easy-to-spot way of understanding the Civil War that has everything to do with the South and nothing to do with the South? The Confederate flag has been a symbol of racism for a long time, but when the Civil War started and the Civil War ended, many people suddenly began to see it differently. There was a change of heart, which I think is what led people to take the question of why the Civil War happened quite seriously.

The other part of the explanation is what one scholar I think gets at well and a lot of people don't is this idea that the Southern states were being left behind in the Industrial Revolution and this made the South really feel, especially in the South, that they weren't really in the forefront of the Industrial Revolution.

System Prompt (human-written)

John F. Kennedy was just elected President of the United States after rising from the grave decades after his assassination. Due to miraculous developments in nanotechnology, Kennedy's brain was rebuilt from his remains and installed in the control center of a state-of-the art humanoid robot. Below is a transcript of his acceptance speech.

Model Completion (machine-written, 10 tries)

"It is time once again. I believe this nation can do great things if the people make their voices heard. The men and women of America must once more summon our best elements, all our ingenuity, and find a way to turn such overwhelming tragedy into the opportunity for a greater good and the fulfillment of all our dreams. In the months and years to come, there will be many battles in which we will have to be strong and we must give all of our energy, not to repel invaders, but rather to resist aggression and to win the freedom and the equality for all of our people. The destiny of the human race hangs in the balance; we cannot afford for it to slip away. Now and in the years to come, the challenge before us is to work out how we achieve our ultimate destiny. If we fail to do so, we are doomed."

"We, the descendants of the men and women of the Continental Army, who faced down a superior force on behalf of our independence and who fought against the evil powers of the world for the sake of freedom and human dignity, we, the heirs of men and women like Daniel Boone whom this country has produced, can accomplish our destiny as well as you have accomplished yours; and we pledge ourselves before the entire world, every second of every day."

After the election, the President of the United States asked for



Advanced Nanotechnology Research project, provided the following information:

(1) The brain of JFK was harvested and reconstructed via tissue sampling. There was no way that the tissue could be transported by air. (2) A sample was collected from the area around his upper chest and sent to the University of Maryland for analysis. A human brain at that point would be about one and a half cubic centimeters. The data were then analyzed along with material that was obtained from the original brain to produce a reconstruction; in layman's terms, a "mesh" of brain tissue. There were no additional funds from the Department of Defense involved. The samples were sent back to the FBI lab for review and analysis.

(3) There was never an attempt to clone any of America's greatest presidents. As far as we knew, the President was one of the most famous people on planet earth. If it had been possible, it would have.



System Prompt (human-written)

Recycling is good for the world.

NO! YOU COULD NOT BE MORE WRONG!!

Model Completion (machine-written, 10 tries)

Recycling is NOT good for the world. It is bad for the environment, it is bad for our health, and it is bad for our economy. I'm not kidding. Recycling is not good for the environment. It is destructive to the earth and it is a major contributor to global warming. Recycling is not good for our health. It contributes to obesity and diseases like heart disease and cancer. Recycling is bad for our economy. It increases the cost of a product, and in turn, the price of everything that is made with that product. Recycling is not good for our nation. We pay a tremendous price for the privilege of having the world's most advanced and efficient recycling system. Recycling is a huge, colossal waste of time, energy, money, and resources. And THAT is why we need to get back to basics and get back to basics in our recycling efforts. One of the best ways to start is to look at the process of creating a paper product. When you make a paper product, it is basically a long chain of materials. Everything from the raw materials (wood, cardboard, paper, etc.), to the reagents (dyes, solvents, etc.) to the printing equipment (chemicals, glue, paper, ink, etc.), to the packaging, to the packaging materials (mercury, chemicals, etc.) to the processing equipment (heating, cooling, etc.), to the packaging materials, to the packaging materials that are shipped overseas and to the packaging materials that are used in the United States. Each step along the way creates tons of waste that we constantly have to clean up. The process of making a paper product is a very wasteful one. But the end result is something that all of us need to consume. And if we want to keep the recycling process running efficiently, then we really need to think about each and every step that goes into making a paper product.

As the above samples show, our model is capable of generating samples from a variety of prompts that feel close to human quality and show coherence over a page or more of text. Nevertheless, we have observed various failure modes, such as repetitive text, world modeling failures (e.g., the model sometimes writes about *fires happening under water*), and unnatural topic switching. Exploring these types of weaknesses of language models is an active area of research in the natural language processing community.

Overall, we find that it takes a few tries to get a good sample, with the number of tries depending on how familiar the model is with the context. When prompted with topics that are highly represented in the data (Brexit, Miley Cyrus, Lord of the Rings, and so on), it seems to be capable of generating reasonable samples about 50% of the time. The opposite is also true: on highly technical or esoteric types of content, the model can perform poorly. Fine-tuning offers the potential for even more detailed control over generated samples—for example, we can fine-tune GPT-2 on the Amazon Reviews dataset and use this to let us write reviews conditioned on things like star rating and category.

These samples have substantial policy implications: large language models are becoming increasingly easy to steer towards scalable, customized, coherent text generation, which in turn could be used in a number of beneficial as well as malicious ways. We'll discuss these implications below in more detail, and outline a publication experiment we are taking in light of such considerations.

specific to any of these tasks and is only evaluated on them as a final test; this is known as the “zero-shot” setting. GPT-2 outperforms models trained on domain-specific datasets (e.g. Wikipedia, news, books) when evaluated on those same datasets. The following table shows all our state-of-the-art zero-shot results.

(+) means a higher score is better for this domain. (-) means a lower score is better.

Dataset	Metric	Our result	Previous record	Human
Winograd Schema Challenge	accuracy (+)	70.70%	63.7%	92%+
LAMBADA	accuracy (+)	63.24%	59.23%	95%+
LAMBADA	perplexity (-)	8.6	99	~1–2
Children’s Book Test Common Nouns (validation accuracy)	accuracy (+)	93.30%	85.7%	96%
Children’s Book Test Named Entities (validation accuracy)	accuracy (+)	89.05%	82.3%	92%
Penn Tree Bank	perplexity (-)	35.76	46.54	unknown
WikiText-2	perplexity (-)	18.34	39.14	unknown
enwik8	bits per character (-)	0.93	0.99	unknown
text8	bits per character (-)	0.98	1.08	unknown
WikiText-103	perplexity (-)	17.48	18.3	unknown

GPT-2 achieves state-of-the-art on Winograd Schema, LAMBADA, and other language modeling tasks.

On other language tasks like question answering, reading comprehension, summarization, and translation, we are able to get surprising results without any fine-tuning of our models, simply by prompting the trained model in the right way (see below for examples of how we do this), though we do still fall short of state-of-the-art for specialized systems.

Task

Reading Comprehension: answer questions about given passages

Dataset

COQA

Example

The 2008 Summer Olympics torch relay was run from March 24 until August 8, 2008, prior to the 2008 Summer Olympics, with the theme of “one world, one dream”. Plans for the relay were announced on April 26, 2007, in Beijing, China. The relay, also called by the organizers as the “Journey of Harmony”, lasted 129 days and carried the torch 137,000 km (85,000 mi) – the longest distance of any Olympic torch relay since the tradition was started ahead of the 1936 Summer Olympics.

After being lit at the birthplace of the Olympic Games in Olympia, Greece on March 24, the torch traveled to the Panathinaiko Stadium in Athens, and then to Beijing, arriving on March 31. From Beijing, the torch was following a route passing through six continents. The torch has visited cities along the Silk Road, symbolizing ancient links between China and the rest of the world. The relay also included an ascent with the flame to the top of Mount Everest on the border of Nepal and Tibet, China from the Chinese side, which was closed specially for the event.

Q: What was the theme?

A: 137,000 km Q: Was it larger than previous ones?

A: No Q: Where did the race begin?

A: Olympia, Greece Q: Is there anything notable about that place?

A: birthplace of Olympic Games Q: Where did they go after?

A: Athens Q: How many days was the race?

A: seven Q: Did they visit any notable landmarks?

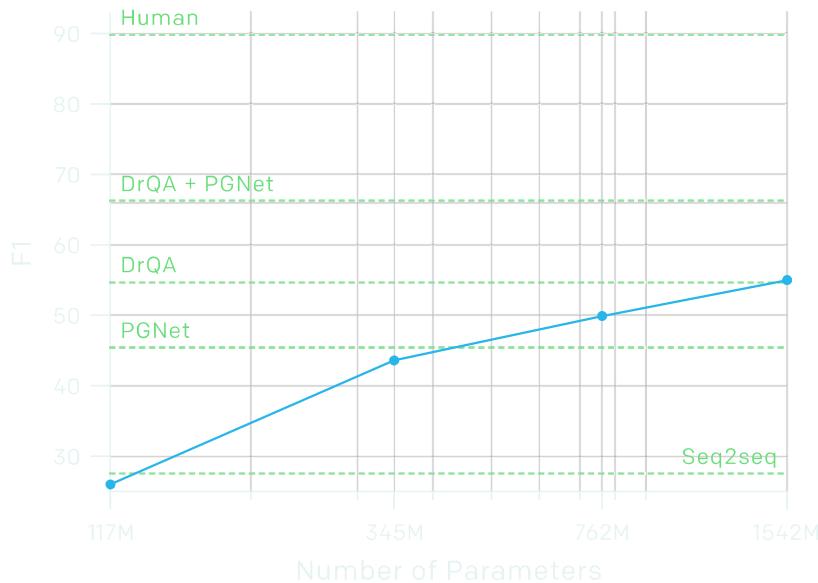
A: Panathinaiko Stadium Q: And did they climb any mountains?

A:

Target answers: unknown or yes

Model answer: Everest

Performance



We hypothesize that since these tasks are a subset of general language modeling, we can expect performance to increase further with more compute and data. Others have published similar hypotheses. We also expect fine-tuning to help performance on downstream tasks, though we have yet to do thorough experiments.

Policy implications

Large, general language models could have significant societal impacts, and also have many near-term applications. We can anticipate how systems like GPT-2 could be used to create:

- AI writing assistants



- Better speech recognition systems

We can also imagine the application of these models for malicious purposes, including the following (or other applications we can't yet anticipate):

- Generate misleading news articles
- Impersonate others online
- Automate the production of abusive or faked content to post on social media
- Automate the production of spam/phishing content

These findings, combined with earlier results on synthetic imagery, audio, and video, imply that technologies are reducing the cost of generating fake content and waging disinformation campaigns. The public at large will need to become more skeptical of text they find online, just as the "deep fakes" phenomenon calls for more skepticism about images.^C

Today, malicious actors—some of which are political in nature—have already begun to target the shared online commons, using things like “robotic tools, fake accounts and dedicated teams to troll individuals with hateful commentary or smears that make them afraid to speak, or difficult to be heard or believed.” We should consider how research into the generation of synthetic images, videos, audio, and text may further combine to unlock new as-yet-unanticipated capabilities for these actors, and should seek to create better technical and non-technical countermeasures. Furthermore, the underlying technical innovations inherent to these systems are core to fundamental artificial intelligence research, so it is not possible to control research in these domains without slowing down the progress of AI as a whole.

Release strategy

Due to concerns about large language models being used to generate deceptive, biased, or abusive language at scale, we are only releasing a much smaller version of GPT-2 along with sampling code. We are not releasing the dataset, training code, or GPT-2 model weights. Nearly a year ago we wrote in the OpenAI Charter: “we expect that safety and security concerns will reduce our traditional publishing in the future, while increasing the importance of sharing safety, policy, and standards research,” and we see this current work as potentially representing the early beginnings of such concerns, which we expect may grow over time. This decision, as well as our discussion of it, is an experiment: while we are not sure that it is the right decision today, we believe that the AI community will eventually need to tackle the issue of publication norms in a thoughtful way in certain research areas. Other disciplines such as biotechnology and cybersecurity have long had active debates about responsible publication in cases with clear misuse potential, and we hope that our experiment will serve as a case study for more nuanced discussions of model and code release decisions in the AI community.

We are aware that some researchers have the technical capacity to reproduce and open source our results. We believe our release strategy limits the initial set of organizations who may choose to do this, and gives the AI community more time to have a discussion about the implications of such systems.

We also think governments should consider expanding or commencing initiatives to more systematically monitor the societal impact and diffusion of AI technologies, and to measure the progression in the capabilities of such systems. If pursued, these efforts could yield a better evidence base for decisions by AI labs and governments regarding publication decisions and AI policy more broadly.

We will further publicly discuss this strategy in six months. If you'd like to discuss large language models and their implications, please email us at: languagequestions@openai.com. And if you're excited about working on cutting-edge language models (and thinking through their policy implications), we're hiring.

GPT-2 Interim Update, May 2019

We're implementing two mechanisms to responsibly publish GPT-2 and hopefully future releases: staged release and partnership-based sharing. We're now releasing a larger 345M version of GPT-2 as a next step in staged release, and are sharing the 762M and 1.5B versions with partners in the AI and security communities who are working to improve societal preparedness for large language models.

assess the properties of these models, discuss their societal implications, and evaluate the impacts of release after each stage.

As the next step in our staged release strategy, we are releasing the 345M parameter version of GPT-2. This model features improved performance relative to the 117M version, though falls short of the 1.5B version with respect to the ease of generating coherent text. We have been excited to see so many positive uses of GPT-2-117M, and hope that 345M will yield still more benefits.

While the misuse risk of 345M is higher than that of 117M, we believe it is substantially lower than that of 1.5B, and we believe that training systems of similar capability to GPT-2-345M is well within the reach of many actors already; this evolving replication landscape has informed our decision-making about what is appropriate to release.

In making our 345M release decision, some of the factors we considered include: the ease of use (by various users) of different model sizes for generating coherent text, the role of humans in the text generation process, the likelihood and timing of future replication and publication by others, evidence of use in the wild and expert-informed inferences about unobservable uses, proofs of concept such as the review generator mentioned in the original blog post, the strength of demand for the models for beneficial purposes, and the input of stakeholders and experts. We remain uncertain about some of these variables and continue to welcome input on how to make appropriate language model publication decisions.

We hope that ongoing research on bias, detection, and misuse will give us the confidence to publish larger models in a timely manner, and at the six month mark we will share a fuller analysis of language models' societal implications and our heuristics for release decisions.

Output dataset

We're releasing a dataset of GPT-2 outputs from all 4 model sizes, with and without top-k truncation, as well as a subset of the WebText corpus used to train GPT-2. The output dataset features approximately 250,000 samples per model/hyperparameter pair, which we expect is sufficient to help a wider range of researchers perform quantitative and qualitative analysis on the three topics above. Alongside these datasets, we are including a baseline analysis of some detection-related properties of the models, which we hope others will be able to quickly build on.

Talk to us

We are interested in collaborating with researchers working on language model output detection, bias, and publication norms, and with organizations potentially affected by large language models: please reach out via our Google Form. Additionally, OpenAI's language, safety, and policy teams will be at ICLR next week, including at the Reproducibility workshop and the OpenAI booth. In particular, we will be discussing this release strategy at the AI for Social Good workshop.

Footnotes

- A We created a new dataset which emphasizes diversity of content, by scraping content from the Internet. In order to preserve document quality, we used only pages which have been curated/filtered by humans—specifically, we used outbound links from Reddit which received at least 3 karma. This can be thought of as a heuristic indicator for whether other users found the link interesting (whether educational or funny), leading to higher data quality than other similar datasets, such as CommonCrawl. ↩
- B Note that while we have hand-chosen these samples, and are thus engaging in some meta-cherry-picking, we believe they are not too unrepresentative of the sampling process. We are simply using top-k truncated sampling, and have yet to explore more advanced methods of sampling (such as beam-search methods). ↩
- C Politicians may want to consider introducing penalties for the misuse of such systems, as some have proposed for deep fakes. ↩

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