Harnessing Toulmin's theory for zero-shot argument explication

Anonymous ACL submission

Abstract

To better analyze informal arguments on public forums, we propose the task of *argument explication*, which makes explicit a text's argumentative structure and implicit reasoning by outputting triples of propositions ⟨*claim*, *reason*, *warrant*⟩. The three slots, or argument components, are derived from the widely known Toulmin (1958) model of argumentation. While prior research applies Toulmin or related theories to annotate datasets and train supervised models, we develop an effective method to prompt generative large language models (LMs) to output explicitly named argument components proposed by Toulmin by prompting with the theory name (e.g. `'According to Toulmin model'`). We evaluate the outputs' coverage and validity through a human study and automatic evaluation based on prior argumentation datasets, and perform robustness checks over alternative LMs, prompts, and argumentation theories. Finally, we conduct a proof-of-concept case study to extract an interpretable argumentation (hyper)graph from a large corpus of critical public comments on whether to allow the COVID-19 vaccine for children, suggesting future directions for corpus analysis and argument visualization.

1 Introduction

Advances in computational methods for analyzing arguments have benefited various applications spanning debating technologies (Aharoni et al., 2014; Rinott et al., 2015), policymaking (Sardianos et al., 2015), information retrieval (Carstens and Toni, 2015), essay writing support (Stab and Gurevych, 2017) and legal decision making (Palau and Moens, 2009). However, unlike these domains with well-written arguments, web discourse on social media and public forums features arguments from inexperienced writers, often consisting of unclear argumentative structures and reasoning, making argument analysis quite challenging. Manual interpretation of such arguments is especially problematic in eRulemaking, where government officials are required to make sense of large amounts of public feedback (Lawrence et al., 2017).

To help automate the analysis of such informal arguments, we propose the task of *argument explication*, which involves making the *structure* and *implicit reasoning* of an argument explicit. In particular, we decompose a natural language argument into its claim and reasons. We further elucidate its reasoning by explicitly stating an implicit warrant that logically links a reason to the claim.

Argument explication can be useful for many applications. For instance, as shown in Figure 1, it can help lay out the reasoning involved in public comments, enabling quick comprehension of arguments being made. It could help identify fallacious arguments by clearly laying out an argument's logical structure (Deshpande et al., 2023), or aid theme discovery by improving text representation with implicit content (Viswanathan et al., 2023; Hoyle et al., 2023). It can also assist other NLP tasks (e.g., question-answering), where the explicated output could serve as intermediate reasoning, a method that has been demonstrated to improve downstream LM performance (Wei et al., 2022).

Traditionally, several argumentation theories (e.g., Toulmin, 1958; Freeman, 1991; Walton, 1996) have been proposed to analyze arguments, guiding the development of training datasets and supervised models trained on them (Habernal and Gurevych, 2017; Stab and Gurevych, 2017; Skeppstedt et al., 2018). Recent advances in NLP, driven by large language models (Brown et al., 2020a; Touvron et al., 2023), have led to a new modeling approach using specific keywords or phrases as prompts to guide model responses (Wei et al., 2022; Kojima et al., 2022), with little or no training data. This approach is especially promising for argument analysis, traditionally dependent on bespoke and smaller datasets (Morio et al., 2022) compared to other NLP tasks, as it could enable the analysis of unstructured argumentative texts without requiring extensive domain-specific annotations. However,

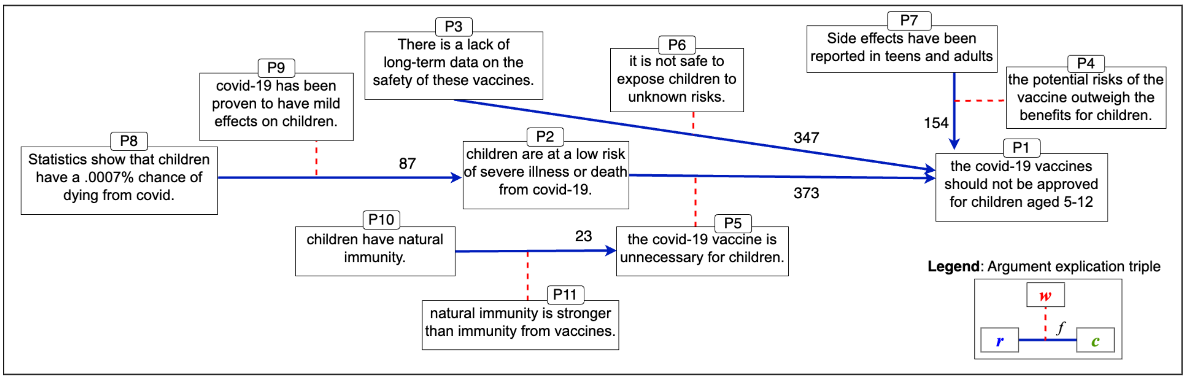

P3
There is a lack of long-term data on the safety of these vaccines.
P6
it is not safe to expose children to unknown risks.
P7
Side effects have been reported in teens and adults
P9
covid-19 has been proven to have mild effects on children.
P4
the potential risks of the vaccine outweigh the benefits for children.
154
347
P8
Statistics show that children have a .0007% chance of dying from covid.
87
P2
children are at a low risk of severe illness or death from covid-19.
P1
the covid-19 vaccines should not be approved for children aged 5-12
373
P10
children have natural immunity.
23
P5
the covid-19 vaccine is unnecessary for children.
P11
natural immunity is stronger than immunity from vaccines.
Legend: Argument explication triple
w
f
r
c

Figure 1: A portion of the corpus-level argument hypergraph[1] we automatically extract from regulations.gov public comments on whether to approve a COVID-19 vaccine for children. Each node is a cluster of propositions extracted from comments. An argument is a triple of nodes, ⟨(c)laim, (r)eason, (w)arrant⟩, visualized as *solid blue* and *dotted red* arrows connecting the explicit and implicit supporting propositions (r, w) to the claim (c). f is the triple's corpus frequency. Further details in §6.

the pathway from explicit argumentation theories to prompting-based model design in the era of LMs is less well-defined.

In this work, we harness Toulmin's model of argumentation for zero-shot argument explication. Toulmin's theory proposes a schema to analyze arguments and has been commonly used to annotate real-world arguments (Habernal and Gurevych, 2017), suggesting its practical utility. This theory also has a substantial scholarly impact; for example, Google Scholar citations for Toulmin's theory (21,177) are close to Chomsky, 1957 (31,647). Beyond academic communities, this theory is also widely popular for its pedagogical use (Ellis, 2015). For instance, in a random sample of 100 documents from C4[2] (Dodge et al., 2021) mentioning *Toulmin*, we find that 21% contain worked-out examples of Toulmin-style argument breakdown, potentially serving as supervised training data in LMs' pretraining corpora. Motivated by these observations, we investigate the use of Toulmin's theory for the zero-shot argument explication task.

Our major contributions include:

- We propose the argument explication task and provide a two-stage framework to explicate arguments: identifying the claim and reasons, and then generating a warrant for each claim-reason pair. For each stage, we prompt an LM with `'According to Toulmin model,'` which elicits a theory-compliant response with correct mentions of Toulmin's terminology (§5.3) and generates reasonable values for each of these terms (§5.4).
- We further validate our results via prompt sensitivity analysis (§5.5) and comparison with other argumentation theories (§5.6). Our analysis shows that prompting with references to Toulmin's theory consistently yields better performance than other theories.
- Finally, to illustrate the usefulness of our approach and argument explication task more broadly, we apply it to a corpus of public comments related to COVID-19 vaccine approval for children (§6), visualizing them as a corpus-level argument hypergraph (Figure 1), which could be useful in drawing insights and help inform civic decision-making.

2 Related Work

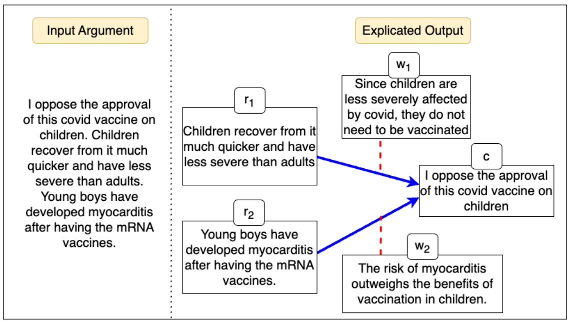
Our work is related to several areas:

Argument mining involves claim-reason identification from an input argument and thus focuses on analyzing explicit content (Stab and Gurevych, 2014, 2017; Bentahar et al., 2010), while our task requires generating implicit information as well.

Argument reasoning only focuses on generating implicit information, while assuming a prior knowledge of claim and reason (Habernal and Gurevych, 2017; Becker et al., 2020b; Chakrabarty et al., 2021; Boltužić and Šnajder, 2016), which is not available when analyzing real-world arguments. In contrast, our task requires identifying claim-reason pairs before generating implicit information. Hulpus et al. (2019) investigate the end-to-end task of identifying the structure and reasoning of an argument, however only theoretically. Becker et al. (2020a) address some relevant subtasks proposed by Hulpus et al. (2019), however, they also assume pre-identified claim-reason pairs.

[2] A corpus often used to pre-train LMs (Raffel et al., 2020).

[2] Unlike a graph, a hypergraph edge—here, an argument triple ⟨c, r, w⟩—can connect more than two nodes.



I oppose the approval of this covid vaccine on children. Children recover from it much quicker and have less severe than adults. Young boys have developed myocarditis after having the mRNA vaccines.

Since children are less severely affected by covid, they do not need to be vaccinated

Children recover from it much quicker and have less severe than adults

I oppose the approval of this covid vaccine on children

Young boys have developed myocarditis after having the mRNA vaccines.

The risk of myocarditis outweighs the benefits of vaccination in children.

Figure 2: Illustrative example of an input argument decomposed into two explication triples of explicit reasons (r_i) and implicit warrants (w_i).

Argument synthesis involves generating an argument from scratch (El Baff et al., 2019; Wachsmuth et al., 2018; Gretz et al., 2020), while our task involves generating output conditioned on an input argument.

Argument mapping: While prior work has also explored visualizing arguments as maps, they have mainly focused on visualizing individual arguments (Reed, 2001) or supporting online collaborative tools, where members of a community work together to manually build an argument map (Klein, 2012). In contrast, we aim to automate the construction of a corpus-level argument hypergraph by analyzing arguments within an existing corpus.

LMs for computational argumentation have just started being explored. Chen et al. (2023) treat argument mining as a classification task, and do not consider generating implicit information. Rocha et al. (2023) consider augmenting an argument with implicit information using LMs, though only focus on explicating discourse markers.

3 Argument Explication Task

Explicating an argument involves a) identifying its *structure*: determining its claim and reasons, and b) explaining its *reasoning*: making explicit any implicit information connecting the reason to the claim. Following several argumentation theories, we propose decomposing an argument into three core components:[3]

The ***claim*** (c) is a normative assertion or point of view put forward by the author for general acceptance. It is also known as *conclusion* (Toulmin, 1958; Walton, 1996; Freeman, 1991).

A ***reason*** (r_i) is a proposition provided by the author to convince the audience why they should accept the claim. Toulmin (1958) refers to it as *data*, and later *grounds* in Toulmin et al. (1984); others use the term *premise* (Walton, 1996; Freeman, 1991). As explained by Toulmin, '*the data represent what we have to go on.*'

The ***warrant*** (w_i) provides a logical link between reason and claim, encoding the author's current presupposed world knowledge that explains why c follows from the provided r_i. A warrant is a missing piece of information that is taken for granted by the author and is assumed common knowledge, yet if it fails to hold, c cannot be inferred from the r_i. As per Toulmin (1958): '*data are appealed to explicitly, warrants implicitly.*' It is also similar to Walton (1996)'s *major premise*.

We consider singled-authored arguments proposing a single claim, in line with public comments, where the majority of them express support or objection to a specific policy issue. The author may give one or more reasons to support this claim. For every claim-reason pair, there exists a corresponding warrant. In cases where a reason sufficiently supports the claim, a trivial warrant of the form 'if reason then claim' may suffice.

Formally, the task input is a textual argument T, and its output is a collection of explication triples, $E = \{\langle c, r_i, w_i \rangle\} \; \forall \; i{=}1$ to N, with the same claim appearing in all triples. Figure 2 illustrates two connected triples for an input argument.

4 Method: A two-stage framework

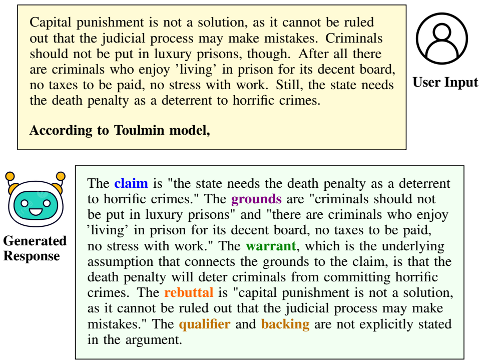
We explicate an argument in two stages. In stage 1, we generate the claim (c) and all the reasons (r_i) from the input argument. In stage 2, we generate the warrant (w_i) between each claim-reason pair identified in stage 1.[4] Stage 2 facilitates the generation of warrants for every claim-reason pair, enabling us to fully explicate the argument. In both stages, we prompt LMs in a zero-shot setting, prompting with references to Toulmin's theory, as elaborated next.

4.1 Prompting with references to Toulmin's theory for zero-shot argument explication

Background on Toulmin's theory: Toulmin's model breaks down an argument into three core components—*claim*, *data/grounds*, and *warrant*—which directly map to the components of the argument explication task. It also has three optional components including *backing* (additional support

[3] A number of other argument components have been proposed by the cited theories, briefly reviewed in Appendix C.

[4] We also considered providing the input argument as the context in stage 2 but found no difference in the generated warrant with or without context. Thus, we omitted context in stage 2 to reduce prompt tokens and hence cost.



Capital punishment is not a solution, as it cannot be ruled out that the judicial process may make mistakes. Criminals should not be put in luxury prisons, though. After all there are criminals who enjoy 'living' in prison for its decent board, no taxes to be paid, no stress with work. Still, the state needs the death penalty as a deterrent to horrific crimes.

According to Toulmin model,

The **claim** is "the state needs the death penalty as a deterrent to horrific crimes." The **grounds** are "criminals should not be put in luxury prisons" and "there are criminals who enjoy 'living' in prison for its decent board, no taxes to be paid, no stress with work." The **warrant**, which is the underlying assumption that connects the grounds to the claim, is that the death penalty will deter criminals from committing horrific crimes. The **rebuttal** is "capital punishment is not a solution, as it cannot be ruled out that the judicial process may make mistakes." The **qualifier** and **backing** are not explicitly stated in the argument.

Figure 3: An input argument from MCT and an example response obtained by prompting `GPT-4` with the '`According to Toulmin model`'. The response correctly mentions *terms* from Toulmin's theory and generates plausible *values* for each of these terms.

for warrant), *rebuttal* (a view-point opposing the claim), and *qualifier* (the degree of certainty).

Prompt details: To steer an LM's response as per Toulmin's theory, we utilize the '`According to`' prompt, which has also been shown to improve an LM's ability to ground the information in an external knowledge source (Weller et al., 2023). More specifically, we empirically observe that prompting LMs with '`According to Toulmin model`' ('Toulmin prompt' for brevity) elicits a response that correctly mentions *terms* from Toulmin's theory (e.g., claim, grounds) and generates plausible *values* (propositions) for each term (Figure 3).

Obtaining explication triples from LM's response: We use the Toulmin prompt in both stages of argument explication. In stage 1, we provide a natural language argument (T) as the input. To obtain the argument's claim (c) and reasons (r_i $\forall i$), we extract the values corresponding to the term *claim* and *grounds* (or *data*), respectively from the LM response.[5] For each r_i, we construct a new argument of the form '{r_i}. Therefore, {c}', which we use as input argument in stage 2. Finally, we obtain an explication triple, $\langle c, r_i, w_i \rangle$, by extracting the values corresponding to the terms *claim*, *grounds* (or *data*), and *warrant* from the LM's response obtained in stage 2.[6]

5 Results

5.1 Experimental Details

Evaluation Datasets: We recast the following two datasets to evaluate our method.

ARCT (Habernal and Gurevych, 2017): has 445 claim-reason pairs (test split) sourced from news comments. Each pair has a correct and an incorrect warrant and the goal is to choose the correct one. For our task, we use concatenated claim-reason as the input argument and claim, reason, and correct warrant as the gold explication triple.

Microtext Corpus (MCT; Peldszus and Stede, 2015): has 112 paragraph-length arguments, each annotated with a claim and multiple reasons, based on Freeman (1991)'s theory. *MCT* was later augmented with human-written warrants (Becker et al., 2020b), allowing us to examine the model's ability to generate warrants. Even though this dataset is small in size, it has several advantages: 1) *More complex evaluation dataset*: contains multiple reasons and has argumentative relations between two non-adjacent text spans mimicking real-life arguments. 2) *Not affected by data leakage issues* (Dodge et al., 2021): While the input argument may be present in the pre-training data, the explicit Toulmin-style annotations aren't publicly available online, instead, we interpret them from the original Freeman-style annotations. The original annotations are also in XML, instead of text-to-text format typically used for pre-training LMs.

Language Models: We evaluate LMs of different sizes (40B-175B parameters), including proprietary OpenAI models and open-weight models with publicly available weights. We experiment with all the models in a zero-shot setting, without any fine-tuning. Among OpenAI models, we consider `GPT-3` (`text-davinci-003`; Brown et al., 2020b), `GPT-4` (`gpt4-0613`; OpenAI, 2023). Among open-weight models, we consider `Llama-2-70B` (Touvron et al., 2023) and `Falcon-40B` (Almazrouei et al., 2023) models.[7] Following Kojima et al. (2022); Wei et al. (2022); Wang et al. (2022), we use greedy decoding for all the models.[8]

5.2 Prompting without referring to the Toulmin's theory

Our approach (§4.1) assumes a specific schema to analyze an argument and uses a reference to Toulmin's theory (as prompt) to obtain the argument

[5] We post-process the LM's response into a Python dictionary (with keys as terms and values as the propositions), avoiding complex regex-based information extraction from LM's original response. We use a simple LLM-based post-processor, prompting GPT3.5 with '`Format the above text in a Python dictionary with values as a list of bullet points.`' We manually validated that in over 95% of cases, this step does not introduce errors.

[6] While the claim and reason generated in stage 1 can also be used in final explication triples, empirically we find that they are highly similar to those generated in stage 2.

[7] We use `https://together.ai/` API for inference.

[8] See Appendix A.1 for analysis with varying temperatures.

components. We investigate two baselines without making these assumptions.

Baseline 1 (Without assuming task definition): In this baseline, we abandon both assumptions and use generic prompts to explain an argument without being guided by a specific task definition. We prompt GPT-4 with the three prompts on arguments from MCT: a) 'Explain the logical steps in this argument.'b) 'Explain this argument in a systematic way.' and c) 'Explain this argument in an academic way.' A useful response should analyze and explain argument components, perhaps using any terminology. Only 38.39%, 24.10%, and 21.42% responses obtained by the three prompts respectively include any discussion relevant to the three core argument components (See Appendix B for details). Qualitatively, we found many responses were only paraphrases of the input argument. Although the first prompt elicits some responses with bullet points, for most responses by all three prompts, the model generates open-ended lengthy responses, which are difficult to evaluate, with challenges like hallucinations, difficult human evaluation, an active area of research (Karpinska et al., 2021; Chang et al., 2023).

Baseline 2 (Directly prompt LM to generate argument components): In the second baseline, we assume task definition but still omit reference to Toulmin's theory in the prompt. Instead, we directly ask the LM to generate components defined in the task. Thus, in stage 1, we prompt GPT-4 and LLAMA-2 with 'What is the claim of this argument?' followed by 'What are the reasons provided to support this claim?'. We observe that while these prompts identify the correct component, the responses additionally contain a lot of irrelevant information. For instance, GPT-4 generates reasons in addition to the claim when asked to only generate the claim. Llama-2-70B generates additional questions as continuations in the response, such as 'Is this argument valid?' and provides answers to these questions in the response. We observe the same issue despite limiting the maximum tokens (to generate) to the average component length in a dataset. See §5.4 for a detailed comparison with our approach. Given the low performance in stage 1, we did not investigate this baseline for warrant generation in stage 2.

5.3 Using references to Toulmin's theory

In contrast to generic prompts, the Toulmin prompt generates semi-structured responses, with mentions of theory-relevant *terms* and their *values*. Thus, this prompt offers a consistent output format and the response correctness is straightforward to assess as it is supposed to obey theory definition. We next examine the performance of this prompt in detail.

Datasets	Success Rate (%)			
	GPT4	GPT3	Llama-2-70B	Falcon-40B
ARCT	99.0	94.6	75.2	35.0
MCT	100.0	95.4	90.2	42.5

Table 1: Fraction of responses correctly mentioning all three core terms from Toulmin's theory, across LMs and datasets, via 'According to Toulmin model' prompt.

How often does the Toulmin prompt generate theory-compliant breakdown? We compute success rate, which measures the fraction of arguments for which the LM responses contain all three core terms from Toulmin's theory: *claim*, *grounds* (or *data*), and *warrant*. As shown in Table 1, a large fraction of GPT-4 and GPT-3 responses contain all the core terms suggesting that the model's responses are theory-compliant with high likelihood. Open-weight models also generate theory-compliant breakdowns, although at a lower frequency, with Llama-2-70B performing much better than Falcon-40B. On further analysis of responses generated by the best-performing proprietary model (GPT-4) and open-weight model (Llama-2-70B), we find that many of the responses also contain all six terms from Toulmin's theory (GPT-4: 96.84%, Llama-2-70B: 68.92%). With a low frequency (less than 5%), terms from the other argumentation theories are present in Llama-2-70B, but never appear in GPT-4 responses (see Appendix D for more details), suggesting that the LM's responses conform to Toulmin's theory.

5.4 Examining the quality of explication triples obtained from LM's response

We next examine the quality of triples, $\langle c, r_i, w_i \rangle$, extracted from the LM response (§4.1). Since LMs are known to hallucinate (Maynez et al., 2020; Cao et al., 2022; Ji et al., 2023), it is imperative to examine the correctness of triples before using them for any downstream applications. We examine each of the three components in triples obtained via GPT4 and Llama-2-70B, the best-performing proprietary and open-weight models in terms of success rate.

Automatic evaluation of claim and reasons: We compare generated claims and reasons with gold annotations from ARCT and MCT datasets.

Claim (c): We measure semantic similarity between generated and gold claim, using ROUGE-L (Lin, 2004, n-gram overlap) and BERTScore

Prompt	Model	Dataset	BERTScore		Rouge-L	
			Recall	Precision	Recall	Precision
According to Toulmin model,	GPT4	ARCT	0.99±0.01	0.98±0.01	1.00±0.01	0.98±0.01
		MCT	0.78±0.04	0.79±0.04	0.79±0.05	0.77±0.05
	Llama-2	ARCT	0.64±0.03	0.58±0.03	0.66±0.04	0.52±0.04
		MCT	0.58±0.06	0.58±0.07	0.50±0.08	0.50±0.08
What is the claim of this argument?	GPT4	ARCT	0.95±0.01	0.91±0.02	0.99±0.01	0.90±0.02
		MCT	0.72±0.03	0.58±0.05	0.69±0.05	0.52±0.06
	Llama-2	ARCT	0.50±0.01	0.21±0.02	0.92±0.01	0.08±0.01
		MCT	0.57±0.03	0.17±0.04	0.70±0.04	0.18±0.03

Table 2: Automatic evaluation of the generated claims.

Prompt	Model	Dataset	Recall	Precision
According to Toulmin model,	GPT4	ARCT	0.88±0.03	0.87±0.03
		MCT	0.83±0.05	0.86±0.05
	LLAMA2	ARCT	0.60±0.04	0.59±0.05
		MCT	0.69±0.09	0.74±0.08
What are the reasons provided to support this claim?	GPT4	ARCT	0.91±0.03	0.93±0.02
		MCT	0.82±0.07	0.75±0.05
	LLAMA2	ARCT	0.74±0.04	0.43±0.04
		MCT	0.91±0.05	0.60±0.07

Table 3: Automatic evaluation of the generated reasons.

(Zhang et al., 2020, token-level similarity via contextualized word embeddings). In Table 2, as expected, on ARCT, GPT-4-generated claims exhibit near-perfect scores as it only involves the identification of the claim from two propositions (claim and reason). On MCT with longer arguments, scores are slightly lower, yet the LM responses are correct since the LM resolves coreferences in the generated claims, unlike the gold claims which are spans of the input argument. Llama-2-70B performs reasonably, though the similarity scores are lower than GPT-4. In contrast, when asking both the models to directly generate the claim, the precision drops considerably, suggesting that the LMs additionally generate a lot of irrelevant information.

Reasons ($r_i,\ \forall i$): Evaluation of reasons is challenging since the number of gold and generated reasons may differ and the generated reasons may not be strict spans of the input argument but light paraphrases. Thus, one-to-one mapping between generated and gold reasons is unknown. To mitigate this issue, we adopt FactScore (Min et al., 2023), which measures whether a proposition is supported by a given context. We use FactScore to measure precision (number of generated reasons supported by the gold reasons) and recall (number of gold reasons supported by generated reasons).[9]

Table 3 shows a high recall and precision on both datasets for GPT-4, suggesting that it can identify all relevant reasons without generating irrelevant information. Llama-2-70B performs reasonably, though the scores are lower than GPT-4. In particular, Llama-2-70B achieves better recall than precision on MCT, implying it identifies all relevant reasons but occasionally generates irrelevant information. In contrast, when both models are asked to directly generate reasons, the precision drops, especially on longer arguments from MCT, suggesting that the LMs generate a lot of irrelevant information in addition to the relevant reasons.

Human evaluation of warrants ($w_i\ \forall i$): Previous studies (Becker et al., 2020b; Boltužić and Šnajder, 2016) have noted variability in collecting gold warrants owing to differing annotator intuitions on what needs to be explicit or what can be taken as granted. This subjectivity results in multiple valid warrants per claim-reason pair, and thus a model-generated warrant could be acceptable even if it differs from gold.[10] Hence, we conduct a human evaluation to assess the quality of warrants.

Given a gold claim-reason pair, we collect acceptability judgments for gold and model-generated warrants. We consider a warrant acceptable if it is: a) relevant and fully explains the link between the claim-reason pair, b) not trivial (of the form ‘if reason then claim’, since each gold claim-reason pair has been annotated with a non-trivial warrant in original datasets), and c) must hold for the claim to be inferred from the reason, even if it does not align with the reader’s personal beliefs. We hired two freelancers on Upwork[11] with graduate-level expertise in English composition and rhetoric, who were shown a claim-reason pair and three warrants (gold, GPT4 and Llama-2-generated; in random order), and were asked to mark all the warrants they consider acceptable. We collected judgments for 150 pairs, with 75 random pairs from ARCT and MCT each. Appendix G provides more details.

Out of 300 judgments for each warrant type, we find that gold warrants are acceptable in 45.7%, GPT-4-generated in 61.7%, and Llama-2-70B in 26.3% cases, suggesting a preference for GPT-4-generated warrants, surpassing gold warrants. Annotators marked a gold warrant unacceptable when it restated the claim, had incorrect wording, was irrelevant to the claim-reason pair, or failed to explain the link between the pair (examples in Appendix G). GPT-4 warrants were mostly considered unacceptable when they repeated the reason, claim, or were of the form ‘if reason then claim’. Fi-

[9] Aggregating pairwise similarity scores between gold and generated reasons can also be used, but we find precision and recall scores more interpretable than an aggregated score.

[10] Similarity between gold and generated warrants is low (for GPT-4, ARCT: 0.3±0.01, MCT: 0.4±0.04; for Llama-2-70B, ARCT: 0.2±0.01, MCT: 0.2±0.01), indicating the model-generated warrants differ from the gold warrants.

[11] https://www.upwork.com/

nally, `Llama-2`-generated warrants, often repeated reason and were acceptable in only a few cases, suggesting that `Llama-2` struggles to generate warrants, requiring further research. Nevertheless, open-weight models exhibit potential, generating Toulmin-style argument breakdown and achieving reasonable claim and reason identification.

5.5 Prompt sensitivity analysis: Can other name references to Toulmin's theory improve performance?

Toulmin's theory can be referenced in various ways (e.g., Toulmin's model/Toulmin's method). Given the prompt sensitivity of language models, we examine the performance across different references.

Extraction of alternative name references: We extract most frequent name references to Toulmin's theory, $N_t = \{n_t^1, n_t^2..n_t^k\}$, from C4 (Raffel et al., 2020), often used for pre-training LMs. Prior efforts have also studied pretraining datasets to measure data contamination (Dodge et al., 2021; Elazar et al., 2023) and its influence on model performance (Magar and Schwartz, 2022; Longpre et al., 2023), we analyze C4 for prompt design. We retrieve documents containing the word *Toulmin*[12] and identify sentences mentioning the same surname. From each sentence, we extract simple noun phrases containing common terms describing a construct (e.g., model, method, schema). After a manual review for relevance to the theorist, we compile a list of name references with their n-gram counts in C4 (Table 4); See Appendix E for more details.

The 'Toulmin model' reference performs best, though other references give comparable performance: Table 4 shows success rates obtained by prompting `GPT-4` and `Llama-2-70B` with different name references. 'Toulmin model' gives the highest success rate, while other references, both moderate-frequency (e.g., Toulmin's model) and low-frequency (e.g., Toulmin argument model), yield comparable results. Table 4 and Figure 4 also show that `GPT4`'s performance varies less across name references, while `Llama-2-70B` exhibits greater variability, suggesting that `GPT4` is more robust to prompt variations. Finally, `Llama-2-70B` exhibits a moderate correlation between the success rate and frequency of a name reference (Spearman's correlation, ρ=0.56, though statistically non-significant with p=0.2), while GPT4 shows near zero correlation (ρ=0.04), indicating that open-weight models could benefit from optimizing prompt based on occurrence frequency.

Name Reference (n_t^i)	C4 Corpus Frequency (n-gram counts)	Success Rate (%)	
		`GPT-4`	`Llama-2-70B`
(the) Toulmin model	2415	97.42	67.27
(the) Toulmin method	531	95.20	61.38
Toulmin's model	162	96.00	67.12
(the) Toulmin('s) Schema	137	96.13	61.48
(the) Toulmin('s) approach	87	95.50	56.75
Toulmin argument strategies	41	95.60	27.47
Toulmin's argument(ation) model	28	96.88	61.48

Table 4: Success rate of LMs on the ARCT dataset when prompted with '`According to` n_t^i,' where n_t^i is a name reference to the Toulmin's theory.

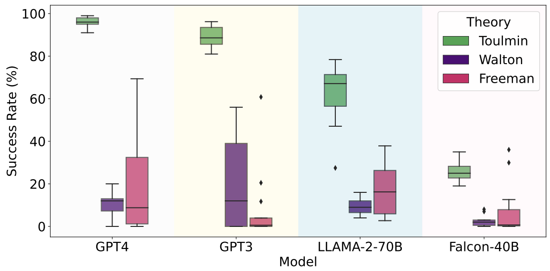


Figure 4: Across all LMs, prompting with references to Toulmin's theory results in highest success rate.

5.6 Can name references to alternative theories improve performance?

We investigate whether the prevalence of a theory (aggregate frequency of all name references to a theory) in LM's pretraining data correlates with its performance on the task. We examine two alternative theories, namely, Walton's argumentation schemes (Walton et al., 2008) and Freeman's theory of argument structure (Freeman, 1991), which are less frequently mentioned on the web[13] but often used in computational research (Habernal and Gurevych, 2017) and for annotation purposes (e.g., MCT used in this work is annotated according to Freeman's theory). Both theories are also relevant to the argument explication task, as they have similar core components as Toulmin, though use different terminology.

Figure 4 shows success rate distribution, when prompted with name references to the three theories,[14] across four LMs on the ARCT dataset. References to Toulmin's theory consistently yield higher success rates than references to other theories across all models, validating our hypothesis. Overall, our findings suggest that the aggregate frequency of references to a theory/concept could be an interesting factor to consider when designing prompts, an interesting avenue for future research.

[12] We use Dodge et al. (2021)'s C4 search engine at `https://c4-search.apps.allenai.org/` for retrieval.

[13] In C4, Toulmin's theory is referenced 3401 times (n-gram counts), Walton's theory 975 times, Freeman's theory 68 times. Appendix F provides counts from other sources.

[14] We use the method from §5.5 to extract name references for Walton and Freeman's theory, details in Appendix E.

6 Case Study: Making sense of public opinion via argument explication

We now illustrate the use of argument explication by analyzing public comments to the FDA on COVID-19 vaccine approval for children. Prior studies used clustering (Hoyle et al., 2023) and topic modeling (Pacheco et al., 2022) to identify the main beliefs (or propositions) held by the public. However, comments are often argumentative, with inferential relations among propositions. Knowing how propositions are interconnected in the broader debate can identify not only what people believe, but also why. For example, if the public health policy has to reduce vaccine hesitancy, officials must know how propositions interconnect in a broader discussion to knock down fallacious arguments.

Method: We use Hoyle et al. (2023)'s corpus of 10,000 public comments sourced from regulations.gov, exhibiting a general vaccine hesitancy. We generate explication triples, $\langle c, r_i, w_i \rangle$, from all comments, via the method outlined in §4.1 using `GPT-4`, excluding single-sentence comments which are often non-argumentative (refinement of this step left for future work). We cluster embeddings[15] of all propositions from the triples, irrespective of their role in triple, using DP-means clustering (Dinari and Freifeld, 2022; Kulis and Jordan, 2012), which automatically determines the number of clusters based on a Euclidean distance threshold. We use a threshold of 0.5, selected via visual inspection of cluster quality. From 9,187 comments, we obtain 14,137 triples and 308 propositional clusters. To identify interconnections between clusters, we represent a proposition with its cluster ID followed by transforming triples of propositions into triples of cluster IDs (TIDs). Each TID, comprised of three cluster IDs, represents a local argument structure mentioned in one or more comments and reveals inferential relations among the corresponding clusters. Overall, we obtain 6,811 unique TIDs, visualized as a hypergraph, where a TID forms a hyperedge and a node is a propositional cluster.

Interpretive analysis of the corpus based on the hypergraph: We draw several interesting insights. Among all the TIDs, 1,862 appear in more than one comment, suggesting that people not only share common beliefs but also use similar argument structures to support their beliefs. Figure 1 shows a fragment of the larger argument hypergraph around the most common argument, (c=P1, r=P2, w=P5), which occurs 373 times; it opposes vaccine approval (c=P1) by saying that children have a low risk from the disease (r=P2). Some comments further elaborate on the backing for P2, by citing low mortality rates from COVID-19 among children (P8), obtained by citing data from government websites. Countering any node in this chain could knock down the entire argument chain. On further exploring the local neighborhood of P1, we find two other frequently mentioned reasons: vaccine side-effects (P7) and lack of long-term testing (P3), consistent with findings from studies of social media discussion on vaccines (Wawrzuta et al., 2021), conferring convergent validity to our approach from a different source.

Explicitly stating warrants also helps reveal the relationship between distinct parts of the hypergraph.[16] Since we cluster all propositions irrespective of their role in a comment, some clusters include both implicit and explicit propositions. For instance, cluster P5 (vaccines are unnecessary for children) includes propositions implied in some comments, while explicit in others. Thus, such clusters bridge distinct parts of the hypergraph.

Overall, we find corpus visualization as a hypergraph promising direction for future work. Graph visualization (among concepts, entities, etc) has been proposed for exploratory corpus analysis (Handler and O'Connor, 2018; Falke and Gurevych, 2017). Complementary to these efforts, our approach can visualize 'arguments' and support complex user queries concerning cluster relations (e.g., 'Why do people think COVID-19 does not affect children?'). Our work lays the groundwork, with potential applications in other argument-rich areas like legal reasoning and peer reviews.

7 Conclusion

Computational analysis of arguments has exciting potential to aid critical analysis of public comments, useful for civic decision-making. In this work, we analyze arguments by making their structure and reasoning explicit, employing LMs in a zero-shot setting and using references to Toulmin's theory as prompts. We validate our approach via robustness across different references and theories. Finally, we illustrate the usefulness of the task in identifying recurring arguments in the COVID-19 vaccine debate, by visualizing them as a corpus-level hypergraph. Overall, we find our approach of visualizing a corpus as a hypergraph promising direction, with exciting potential in other argument-rich areas that could benefit from large-scale analysis of argumentative texts (e.g., legal reasoning).

[15] via `all-mpnet-base-v2` (Reimers and Gurevych, 2019)

[16] A claim-reason pair may be linked by several warrants; for visual clarity, we only display the most frequent one.

8 Limitations

Our quality checks in §5.4 reveal that most of the generated explication triples are deemed reasonable based on human evaluation or measuring similarity with annotations from prior datasets. However, it remains to be studied how generated triples are affected by known political biases of language models (Santurkar et al., 2023). We will explore how these biases could affect our results in future work. Datasets used for evaluating the intrinsic validity of our method (§5.4) may be considered small in size. However, their size is comparable to the size of some datasets in other popular LM evaluation benchmarks. For example, many task datasets in BIG-bench have around 100 examples (Srivastava et al., 2022, Figure 3), which are often used to evaluate zero-shot and few-shot capabilities of LMs. Additionally, this highlights the necessity for low-resource or zero-shot techniques for argument analysis due to the limited size of existing datasets. Finally, in addition to the intrinsic validity, we also demonstrate our method's external validity by applying it to a case study (§6). All our analyses and experiments focus on arguments in the English language and approaches to analyze non-English argumentative text should be explored in future studies. The embeddings used in our case study could be improved further by adapting to the specific domain of interest, thus also improving proposition clustering. The name reference extraction method depends on a noun-phrase detection algorithm, which can be imperfect. Future work can explore other techniques, especially those suited for analyzing informal web text.

9 Ethics Statement

The work is in line with the ACL Ethics Policy. All the models, datasets, and evaluation methodologies used in this work are detailed throughout the text and appendix. The data collection protocol for human evaluation was approved as exempt from institutional review by the coauthors' institution's human subjects research office. All annotators were presented with a consent form (Appendix G) prior to the annotation. They were also informed that only satisfactory performance on the screening example will allow them to take part in the annotation task. Annotators were paid for the time spent on guidelines and taking screening test even if they failed the screening test. All data collected during the annotation study (including annotators‘ feedback) will be released anonymized. We also ensure that the annotators receive at least $15 per hour, above local minimum wage, by adding bonuses to compensate for any additional time spent on the task. We also compensated for the time they spent on clarifying any doubts related to the task. All the datasets were either publicly available or used with the appropriate consent. Finally, besides experiments with language models, we only used AI assistance for content polishing (e.g., spell-checking and paraphrasing).

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Appendix

A Experimental Details

A.1 Choice of Temperature

Prior literature has used various decoding strategies when evaluating LLMs for their zero-shot abilities. For instance (Kojima et al., 2022; Wei et al., 2022; Wang et al., 2022) consider greedy decoding. OpenAI also uses greedy decoding as their default setting for conditional text generation (e.g., summarization, translation, grammar correction, etc.) examples, tasks which are closest to our argument explication task. Some work in summarization and translation (Zhang et al., 2023; Karpinska and Iyyer, 2023) also considers temperature=0.3. We experimented with three temperatures, 0.0, 0.3, and 0.5 on 50 examples from each of the three datasets and found that the generations with different temperatures were semantically very similar to each other, with an average BERTScore (F1) 0.92-0.96 between pair of responses generated by different temperatures. Responses were also similar for different samples generated using the same temperature. As a result, for the sake of simplicity, we keep a temperature of 0.0 in all our experiments. Note that empirically we observe that temp=0 also does not yield deterministic results. However, any variations are minor and relate mostly to lexical word choice, without altering the overall meaning.

B Details of baseline 1

In baseline 1, we experimented with generic prompts. To examine the number of responses that contain any terms relevant to the three core argument components, we searched for the following terms.

1. **Claim:** claim, conclusion, concludes, assertion, posits, advocating
2. **Reason:** reason, premise, evidence, supports
3. **Warrant:** assumption, warrant, implies, implying, suggests, suggesting, implication

The above terms were curated by manually going through all responses by the author. We included any word that could serve a similar function as the argument component name, including verbs (e.g., ‘posits’ or ‘advocating’ for claim).

C Background on argumentation theories

Toulmin’s model of argumentation: Toulmin’s model of argumentation consists of six components (Figure 5). The three fundamental components are:

Claim: The claim or conclusion whose merits author is seeking to establish.

Data: Evidence to establish the foundation of the claim, or, as explained by Toulmin, 'the data represent what we have to go on.' The term was later changed to *grounds*.

Warrant: A logical inference from the grounds to the claim. A warrant could be world knowledge necessary to draw interpretations. As pointed out by Toulmin (1958), "data are appealed to explicitly, warrants implicitly."

Optional components include *backing* (additional support for warrant), *rebuttal* (a view point opposing the claim), and *qualifier* (the degree of certainty).

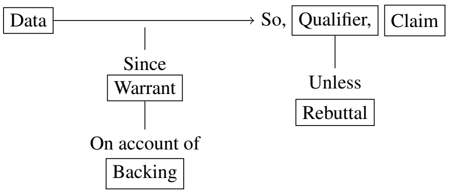


Figure 5: Toulmin's model of argumentation. Nodes represent argument components, the arrows symbolize the explicit support relation, and the lines indicate the authority conferred by one node to the other.

Argument structure by Freeman: Freeman (1991) proposes some key modifications to address issues observed when applying Toulmin's model to real-life argumentative texts (Newman and Marshall, 1991). In particular, Freeman does not distinguish between *data* and *warrant* and regards any evidence provided to support the *conclusion* (similar to *claim* in Toulmin's terminology) as a *premise*. Other components in Freeman's structure include *rebuttal*, *modality* (how strongly the premises support the conclusion), and *counter-rebuttal* (views opposing rebuttal).

Walton's argumentation schemes Walton (1996) proposed a set of argumentation schemes or structures of inference. Each scheme represents a form of everyday reasoning and consists of:

Conclusion: The main point of view.

Minor Premise: Provides evidence to support the conclusion.

Major Premise: An inference rule, similar to the warrant in Toulmin's terminology.

The core components of each of the above theories are related to the components of the argument explication task as listed in Table 5.

	Toulmin	**Walton**	**Freeman**
Claim	Claim	Conclusion	Conclusion
Supporting Premise	Data/Grounds	Minor Premise	Premise
Implicit Premise	Warrant	Major Premise	Premise

Table 5: Mapping between the components of the argument explication task and terminology proposed in each of the argumentation theories.

D Additional analysis of responses generated by Toulmin prompt

What other terms are present in the LM responses? We also investigate the presence of terms that are not part of Toulmin's theory. Some examples contain the term 'conclusion' (`GPT-4`: 12.16%, `Llama-2-70B`: 48.20%). However, this term is unique, as Toulmin (1958) employs 'conclusion' and 'claim' interchangeably to denote the same concept. Some terms from other argumentation theories are present in a small fraction of `Llama-2-70B`'s responses (premise: 2.48%, modality: 0.23%, counterrebuttal: 4.28%, major premise: 1.13%, minor premise: 0.90%). However, these terms do not appear in GPT-4's responses. Overall, the model's responses most often do not contain terms not compliant with Toulmin's theory, suggesting that the LM's responses are predominantly theory-compliant.

E Extraction of theory name references:

We extract the most frequent name references to Toulmin's theory, $N_t = \{n_t^1, n_t^2..n_t^k\}$, from English portion of C4 (C4.EN, Raffel et al., 2020), which is often used for pre-training LMs. For each theory, we retrieve documents[17] containing the theorist's surname[18] and identify sentences mentioning the same surname. For Toulmin, we retrieve 4,805 (4,242 unique) documents; Walton and Freeman yield a large number of matches, we consider the first 10,000 matches, resulting in 9,690 and 9,997 unique documents, respectively.[19] From each sentence containing the theorist's surname, we extract simple noun phrases containing com-

[17] We use Dodge et al. (2021)'s search engine at `https://c4-search.apps.allenai.org/` for retrieval.

[18] Searching via full name filters out relevant documents since informal web discourse may not always use full name references.

[19] Despite more documents for Walton and Freeman, many are false positives as they are more common surnames than Toulmin. According to Forebears (`https://forebears.io/`), covering 27M surnames of 4B people worldwide, approximately 476 individuals have the surname Toulmin, while 156,730 have the surname Walton, and 331,743 have the surname Freeman.

mon terms describing a construct.[20] We use spaCy v3.4.0 (Honnibal and Johnson, 2015) to extract simple noun phrases. After this step, we obtain 888 (127 unique) phrases for Toulmin, 284 (94 unique) for Walton, and 185 (67 unique) for Freeman, all appearing more than once in C4. Notably, noun phrases for Toulmin outnumber those obtained for Walton and Freeman.

After manual filtering for relevance to theorist or argumentation literature (e.g., removal of unrelated references like 'Walton County Local Mitigation Strategy Work Group' and generic/ambiguous phrases like 'argument analysis'), we curate a final list of name references per theory along with their n-gram counts in C4. List of references to Toulmin's theory and Walton's theory are mentioned in Table 4 and Table 6.

Finding references to Freeman's theory is a little challenging. In contrast to Toulmin and Walton, we did not find any relevant phrases for Freeman among noun phrases extracted from C4. Among the automatically extracted noun phrases, none refer to James B. Freeman, instead most refer to scientific work by another scientist (e.g., 'Systematic approaches' by Harold S. Freeman, 'Geologic framework' by Philip A. Freeman). This observation suggests that Freeman's theory is less frequently referenced on the web. Instead, we extracted phrases from scholarly abstracts, S2ORC (Lo et al., 2020), a dataset of academic literature, also intended for language model pre-training. We use the same noun phrase extraction method to obtain the phrases from S2ORC. Table 7 shows the extracted references, with non-zero n-gram counts in C4, indicating that our noun-phrase extraction may overlook some relevant phrases, particularly those with low frequency, suggesting the need for refining name reference extraction in future work. We discuss some limitations of our name reference extraction algorithm next.

Limitation of theory name reference extraction algorithm: The algorithm depends on the noun-phrase extraction algorithm from spaCy, which is not perfect. For instance, consider the sentence, 'The Toulmin model mirrors Cicero's observation.' In this case, spaCy incorrectly identifies 'the Toulmin model mirrors' as a noun phrase. The algorithm also fails sometimes to extract noun phrases from the colloquial text, common on the web. In other cases, it extracts a longer span including verbs (e.g., 'the Toulmin model results', 'Toulmin model shows', 'the "toulmin model" posts', and 'Even the Toulmin model.')

Phrase	Frequency
(The) argumentation schemes	907
Walton's approach	15
Walton's theory	32
Douglas Walton('s) logical argumentation theory	3
Walton's schemes	2
Walton's critical questions method	13
Walton's Argumentation Schemes	1
Walton Douglas's argumentation schemes	2

Table 6: References to Walton's theory extracted from C4, with n-gram counts in C4. The most common phrase *'(The) argumentation schemes'* is also the name of the book by Douglas Walton describing various argumentation schemes (Walton et al., 2008).

Phrase	Frequency
Freeman's method	13
Freeman's theory	31
Freeman's Argument Structure Approach	1
Freeman's Argument Structure	1
Freeman's model	20
Freeman, J.B. (1991)	2

Table 7: References to Freeman's theory extracted from S2ORC corpus, with non-zero n-gram counts in C4.

F Prevalence of name references to theories across different sources

Table 8 mentions the aggregate frequency of name references to a theory across different pre-training corpora and other sources (e.g., Google Scholar citations, Google Books Ngram V3 dataset). For Google Books, we use the service at `https://ngrams.dev/` to extract n-gram counts. We use the n-gram lookup service at `https://wimbd.apps.allenai.org/` for the remaining datasets. Across all sources, name references to Toulmin's theory are much more prevalent than the other theories.

Theory	Citations (Google Scholar)	Counts of n-grams			
		Google Books Ngram V3	C4	The Pile	OSCAR
Toulmin	20,703	18640	4316	493	1724
Walton	2218	11522	975	365	328
Freeman	453	2963	68	25	55

Table 8: Prevalence of name references to different theories across different sources/datasets, illustrating the popularity of Toulmin's theory.

G Human evaluation of warrants

Consent Before participating in our study, we requested every annotator to provide their consent. The annotators were informed about the purpose of the research study, any risks associated with it, and the qualifications necessary to participate. The consent form also elaborated on task details describing what they will be asked to do and how long it will

[20] model(s), method(s), analysis, scheme(s), schema, framework(s), theory(ies), strategy(ies), approach(es), algorithm(s), structure(s). We curated this list by manually examining noun phrases obtained for all three theories.

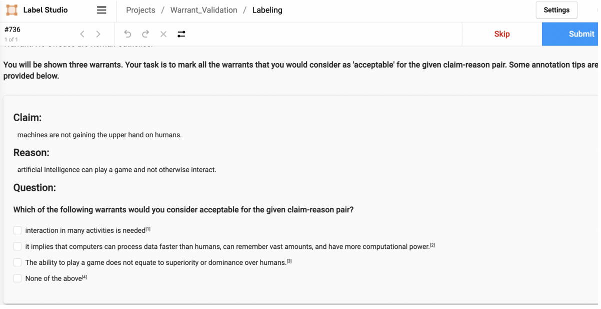
take. The annotators were also informed that they could drop out at any time. Annotators were informed that they would be compensated in the standard manner through the Upwork platform, with the amount specified in the initial Upwork contract. As part of this study, we also collected their level of expertise in English composition and rhetoric. We ensured our annotators that this information would remain confidential in the consent form.

Task setup and guidelines: We show 5 claim-reason pairs, each with 3 associated warrants, and asked annotators to mark ALL the warrants that are acceptable for a given pair. In our guidelines, we provided the following constraints to decide the acceptability of a warrant: a) It is relevant to the claim and the reason. b) It explains the underlying assumption or why the claim logically follows from the reason. c) It is NOT a repetition/paraphrase of the claim or the reason. d) It is NOT simply saying: 'If reason then claim'. e) It should hold true for the claim to be inferred from the reason even if it may not align with your personal beliefs. f) Style of the warrant (e.g., better wording, longer length) does not matter, as long as the content of the warrant links the claim-reason pair. We also provided examples explaining each of these constraints in our guidelines. After reading the guidelines, we asked annotators to take a screening test, which asked basic questions related to the guidelines. This test was intended to mainly test their attention. After passing the screening test, they were asked to annotate 5 claim-reason pairs and provide their reasoning as comments for each annotation. We manually reviewed their comments and after ensuring their understanding of the task, they were asked to annotate 150 claim-reason pairs.

Compensation: Each annotator was paid $0.5 per evaluated claim-reason pair, with an additional $25 bonus to cover the time spent on reading guidelines, completing screening tests, and clarifying any doubts. Altogether, we paid approximately $15 per hour, with a total cost of $200.

Annotation Interface Figure 6 shows a screenshot of the annotation interface used to collect annotations. The annotators were assigned a unique code to log in to the platform, to maintain their anonymity.

Qualitative annotation analysis Table 9 provides some examples of gold warrants that were marked as not acceptable by our annotators.



You will be shown three warrants. Your task is to mark all the warrants that you would consider as 'acceptable' for the given claim-reason pair. Some annotation tips are provided below.

Claim:

machines are not gaining the upper hand on humans.

Reason:

artificial Intelligence can play a game and not otherwise interact.

Question:

Which of the following warrants would you consider acceptable for the given claim-reason pair?

□ interaction in many activities is needed[1]

□ it implies that computers can process data faster than humans, can remember vast amounts, and have more computational power.[2]

□ The ability to play a game does not equate to superiority or dominance over humans.[3]

□ None of the above[4]

Figure 6: A screenshot of annotation platform for human evaluation of warrants.

Claim	Reason	Gold Warrant	Comment
christians have created a harmful atmosphere for gays.	i find the idea that it is a sin to be born or live a life at all to be preposterous.	being gay is considered a sin	reason irrelevant to the claim
foreign language classes should be mandatory in college.	we should be able to speak other languages rather than expect everyone else to speak english.	students should be taking those classes by force	restatement of claim
With those kinds of amounts you think twice about whether you really want to stay in the flat.	they're very bad however, if the rent suddenly climbs by €100 or €200.	If the rent rises from €100 or €200, many cannot afford to stay in the flat.	incorrect wording, "rent rise from €100 or €200" implies €100 or €200 is the base rent
obamacare is sustainable.	taking a cue from the success of the Swiss and Dutch healthcare models proves Obamacare can work, too.	the Swiss and Dutch government is similar to ours	incorrect wording, similar government does not imply similar healthcare models
Brazil should not postpone Olympics.	the Olympics are a dream for many athletes since they train extremely hard.	the athletes won't get sick going to Brazil	warrant fails to explain the link between claim and reason.
public universities are neglecting in-state students.	they want to take advantage of higher tuitions paid by foreign and out of state students.	universities gain additional funds to make more profit	warrant fails to explain the link between claim and reason.
medicare needs to be reformed.	there needs to be some sort of vetting process for advertisers, some of them attempt to scam the elderly.	the elderly are not the only people that are affected	warrant fails to explain the link between claim and reason.

Table 9: Examples of gold warrants marked unacceptable by our annotators, along with their comments explaining why they marked them as unacceptable.