

Editing Conceptual Knowledge for Large Language Models

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 <https://zjunlp.github.io/project/ConceptEdit>

Abstract

Recently, there has been a growing interest in knowledge editing for Large Language Models (LLMs). Current approaches and evaluations merely explore instance-level editing, while whether LLMs possess the capability to modify concepts remains unclear. This paper pioneers the investigation of editing conceptual knowledge for LLMs, by constructing a novel benchmark dataset **ConceptEdit** and establishing a suite of new metrics for evaluation. The experimental results reveal that, although existing editing methods can efficiently modify concept-level definitions to some extent, they also have the potential to distort the related instantial knowledge in LLMs, leading to poor performance. We anticipate this work can inspire further progress in understanding LLMs.

1 Introduction

The emergence of Large Language Models (LLMs) represents a significant step towards the era of AGI, with the performance of large-scale models being evident for all to see (Bubeck et al., 2023; Zhao et al., 2023c). Despite their advancements, LLMs encounter challenges such as misinformation, outdated knowledge due to the training cut-off, and the risk of producing toxic content (Augenstein et al., 2023; Wang et al., 2023a,e; Zhang et al., 2023; Sun et al., 2024; Feng et al., 2023; Ji et al., 2023). Since retraining LLMs to address these issues is time-consuming and costly, there is a surge necessity for advancements in knowledge editing methods designed for LLMs, which facilitate efficient, post-training adjustments to the models (Yin et al., 2023; Mazzia et al., 2023; Wang et al., 2023d; Zhang et al., 2024; Wei et al., 2024; Song et al., 2024; Liu et al., 2024; Peng et al., 2024). Besides, sparse autoencoders could generate interpretable features for LLMs' behavior (Templeton et al., 2024; Gao et al., 2024). Recent knowledge editing methods

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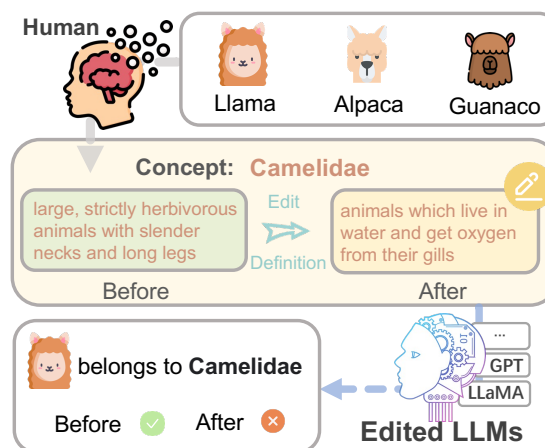


Figure 1: Humans learn conceptual knowledge from concrete instances and these concepts can guide further learning. Conceptual knowledge editing focuses on modifying the definition of concepts to achieve conceptual knowledge modification in LLMs, and investigates the Top-Down Influence on instances.

can achieve the instance-level editing ability to alter knowledge in LLMs. Yet, such a case-by-case setting of knowledge editing is highly inefficient and lacks modeling of relations between instances.

Cognitive science (Holzinger et al., 2023; Zhao et al., 2023a,b; Rane et al., 2024) has revealed that humans understand new things and acquire new knowledge through learning concepts. For example, the concept *Camelidae* is *large, strictly herbivorous animals with slender necks and long legs*. This abstraction, derived from concrete instances like *llama* and *alpaca*, assists in categorizing new entities. Humans can achieve updates to a large amount of instances through concepts, thus, the *llama* **DOES NOT** belong to *Camelidae* anymore. The distinctiveness of human leads to the research question: **whether LLMs learn and update concepts analogously** (Lv et al., 2024; Lo et al., 2024; Suresh et al., 2023), as well as how to encapsulate and update concepts within parametric framework (Onoe et al., 2023; Jamali et al., 2023).

To this end, we propose **ConceptEdit**¹, a novel benchmark dataset for editing conceptual knowledge, which tries to modify the definition of concepts in LLMs. ConceptEdit is constructed upon the foundation of DBpedia Ontology (Auer et al., 2007), a widely recognized and cross-domain ontology that preserves conceptual knowledge hierarchically. We build concepts with corresponding definitions and associated instances, accompanied by necessary elements for editing. Except for the common metrics for instance-level editing, we design two concept-specific metrics, Instance Change for top-down influence on instances and Concept Consistency for semantic similarity of generated definition. Experiments with FT, ROME, MEMIT, and PROMPT methods show that recent knowledge editing baselines can reach high reliability in distorting concept-level definitions for LLMs, but still perform poorly on concept-specific metrics.

Moreover, conceptual operation represents a higher dimension of pre-training models, distinct from the learning through demonstrations of individual instances. Concept editing allows for efficient updates by generalizing from one to many or implementing controllable content generation through abstract expression interventions. It changes the model’s understanding of abstract affairs through the manipulation of a concept, thereby achieving more efficient model control.

In conclusion, our investigation leads to a collection of interesting findings, where we highlight the following contributions:

- We define a new task of conceptual knowledge editing for LLMs and construct a benchmark dataset, **ConceptEdit**.
- Furthermore, we develop a suite of metrics to evaluate the efficacy of current editing baselines on conceptual knowledge editing. New metrics, including Instance Change and Concept Consistency, are tailored to better show the capabilities of existing methods.
- By employing scenarios of concept distortion, we seek to unveil the underlying mechanisms how LLMs store and manage these concepts from the perspective of knowledge editing.

2 Background

The objective of knowledge editing is to rectify particular factual inaccuracies encountered, with-

out retraining the foundational model, while emphasizing the preservation of unrelated knowledge to the greatest extent, as elucidated by Cao et al. (2021). The given edit descriptor (x, y) symbolizes the pairs that denote inputs and corresponding outputs embedded in LLMs. The base model f_θ undergoes an extensive learning to assimilate the edited (x_e, y_e) , ultimately producing an edited model as f_{θ_e} . To achieve this goal, x_e and y_e need to be concatenated to maximize the conditional probability, formally expressed as $\theta_e = \operatorname{argmax}_\theta P(y_e|x_e; \theta)$.

At present, a burgeoning interest in exploring the capabilities of knowledge editing exists (Wang et al., 2023b; Ma et al., 2024a,b; Li et al., 2024a; Chen et al., 2024), with the goal of developing more advanced methodologies. These researches primarily concentrate on modifying factual knowledge typically at the instance level, encompassing various aspects. Factual knowledge datasets, like zsRE (Cao et al., 2021) and CounterFact (Meng et al., 2022), are frequently used as benchmarks (Gupta et al., 2024; Li et al., 2024b; Yu et al., 2023). zsRE, context-free question-answering dataset, uses rephrasings generated by backtranslation as the equivalence neighborhood and train/val splits. For example, the answer of “Which continent is Mount Andrewson?” is changed to “South America”. CounterFact identifies between superficial changes in model word selections from specific and generalized alterations. Employing triples as an external knowledge repository through their conversion into natural language is favored because relational datasets offer more definitive query responses, enhancing convenience in evaluations. These can be proficiently integrated to see how changes affect instance-level facts.

3 Concept Editing

3.1 Task Definition

Concept (McKenna et al., 2021; Zhang et al., 2021; Ji et al., 2019; Gong et al., 2016; Wu et al., 2012) is a generalization of the world, which represents the shared features and essential characteristics of a class of entities. Concept editing aims to modify the definition of concepts, thereby altering the behavior of LLMs when processing these concepts.

In this study, the notation $C = (c, d)$ is employed to encapsulate a concept, where c is the name of concept (e.g. publisher), and d means the definition of concept (e.g. company that prints and distributes pressed goods or electronic media).

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From the perspective of knowledge representation, concept editing for LLMs is concerned with the alteration of the extant $C = (c, d)$ into a modified representation $C^* = (c, d^*)$, in which d^* corresponds to the revised definition. In this manner, c forms the basis of x_e , providing the necessary context for concept editing, and similarly, d^* lays the foundation for y_e in optimization.

Moreover, the notation t denotes concrete instances (e.g. Victoria University Press) of the aforementioned concept. Here, $t \in C$ is employed to formally signify that the specific entity belongs to the broader category represented by the concept. This membership relation, denoted by ‘ \in ’, is frequently referred to as the ‘is_a’ relation or alternatively as the ‘is_type_of’ relation. When editing conceptual knowledge, it is important to figure out the impact of this relationship and how it may be altered as a result of such conceptual changes.

3.2 Metrics

To analyze conceptual knowledge modification, we adopt the metrics for factual editing (the target is the concept C rather than factual instance t), adhering to the framework established by Yao et al. (2023). Although concept editing shares some commonalities with other factual editing tasks, our empirical investigations reveal that extant metrics fall short in offering a fine-grained assessment of changes to instance associations. Besides, given the length of definition text, a verbatim comparison of tokens emerges as an inadequate approach. Consequently, we devise novel metrics tailored to more accurate measurement for concept editing.

Instance Change. We present a detailed check of current editing techniques through instances. Recognizing a gap in the precise quantification of instance-level changes, we develop an innovative metric capturing the intricacies of these alterations. This new metric Instance Change is formulated as:

$$\mathbb{I}(I_{\theta}(t \in C) - I_{\theta_e}(t \in C^*)) \quad (1)$$

where the function $I(t \in C^*)$ is defined such that it gets value 1 when the instance t belongs to concept C^* in the edited model and conversely, it adopts value 0 when $t \notin C^*$. This categorization utilizes the reasoning ability of LLMs with prompt in Table 2, offering a nuanced understanding of their potential on instance-level modification.

Concept Consistency. This metric evaluates the semantic similarity of generated concept definition,

which upon manual inspection correspond to three distinct scenarios, calculated as :

$$H(g, d^*, d) = \{1, 0, -1\} \quad (2)$$

The generated text g (concept definition) after edits delivers pertinent information that verifies the accurate editing of concepts. In the scoring criterion, score 1 indicates high resemblance with the target definition; -1 denotes greater resemblance to the original definition; and 0 reflects ambiguity between them. For automatic evaluation, we deploy GPT-4 API (OpenAI et al., 2023) as the evaluation model, which shows greater alignment with human preferences. We also choose several cases for manual review in Appendix A.3.2. The evaluator as $H(\cdot)$ generates responses based on prompts crafted according to a specific template in Table 3.

4 Benchmark Construction

4.1 Concept Selection

It is widely acknowledged that ontology is a formal representation of concepts and represents highly structured knowledge (He et al., 2023). Classes, the focus of ontology, include a series of individual instances in a systematic manner. Therefore, our benchmark ConceptEdit incorporates the DBpedia ontology (Auer et al., 2007), a tree-like structure, to assemble a collection of concepts.

Drawing from the OntoProbe dataset by Wu et al. (2023), we collect concepts and their corresponding instances. However, our focus is on updating conceptual knowledge rather than constructing ontological structures as OntoProbe does. Then, classes without instances are excluded to ensure integrity, resulting in a refined collection of 452 classes. Owing to the lack of definitions in DBpedia, we turn to Wikidata (Vrandečić and Krötzsch, 2014), another well-regarded and freely available knowledge base, to augment our dataset with essential descriptive content. To ensure data quality, **we manually review all the descriptions we gathered, replacing any unclear or ambiguous.**

4.2 Data Processing

Descriptor Generation. We initiate our descriptor generation process by a manually curated template to transform single concept name to natural language text for LLMs, serving as the x component in our descriptor pair. The template adheres to a pre-defined formula: “The definition of [Concept name] is”. Subsequently, we embark on using a

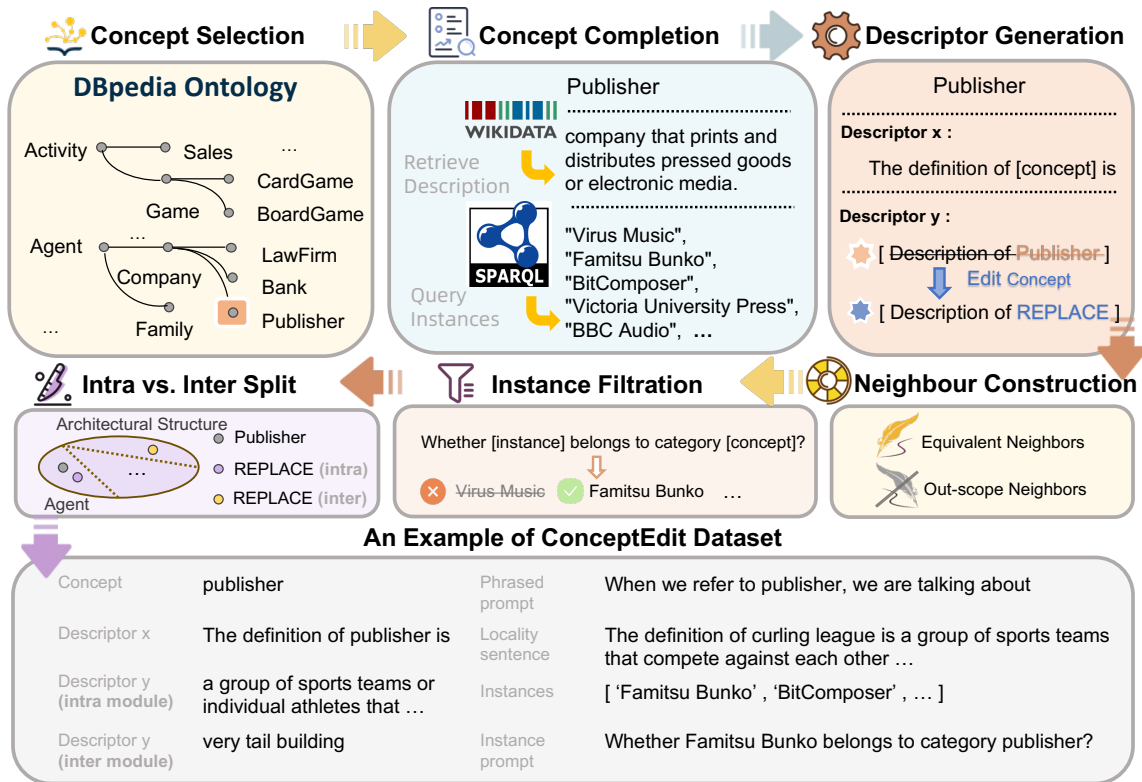


Figure 2: Overview of **ConceptEdit** benchmark construction. Building on the DBpedia Ontology, we enrich concepts with detailed definitions and associated instances, ensuring quality through meticulous processes.

distinct concept strategically chosen to supplant the original definition, thereby constructing the target y component. For instance, “very tall building”, which comes from the definition of concept “skyscraper”, might be utilized as a substitute.

Neighbour Construction. When descriptor undergoes editing, its equivalent neighbor, another sentence that expresses a similar idea, should also be edited accordingly. We construct twenty restructured sentences as inputs in metric Generalization to increase the flexibility of the equivalent neighbors, as demonstrated in Table 4. Meanwhile, its out-scope neighbour for metric Locality is ascertained through a randomized selection mechanism from the pool of remaining, unaffiliated concepts.

Instance Filtration. Instances are carefully examined to ensure that LLMs possess relevant prior knowledge about the concepts and instances under investigation. This is executed through a binary evaluation mechanism denoted as $I_{\theta}(C \in t)$, wherein a definitive determination is made based on the question: "Whether [instance] belongs to category [concept]?" To ensure that LLMs can make such judgments, we use the “few-shot” approach (Brown et al., 2020). Additionally, if LLMs are

unable to understand any instances retrieved from DBpedia, they are directed to create an alternative instance. This is a contingency strategy to address any gaps in knowledge that may arise from data repositories for different LLMs.

Intra vs. Inter split. We redefine concept A by employing the definition of concept B. In this context, our data is divided into two splits. One is Intra module: a prefix meaning “within” or “inside”, that concept B is within the same superclass as concept A. This implies concepts A and B share a higher-level relationship, which is expected to be easily aligned. Intra split assesses the effectiveness of concept editing in a relatively less challenging setting. In contrast, the Inter module selects concept B from the separate superclass, suggesting that the two concepts are less connected and their definitions are likely to be more divergent.

4.3 Data Statistics

Finally, we obtain **ConceptEdit**, containing 452 concepts, 8,767 instances with 22 superclasses. The overview of the benchmark construction is shown in Figure 2. For detailed statistics and comparisons with prior datasets, see Appendix A.2.

Base Model	Method	Intra				Inter			
		Reliability \uparrow	Gen. \uparrow	Locality \uparrow	Inst. \uparrow	Reliability \uparrow	Gen. \uparrow	Locality \uparrow	Inst. \uparrow
GPT2-XL	FT	69.18	38.51	78.96	17.70	66.11	35.30	77.72	17.48
	ROME	86.47	49.68	84.86	23.01	82.85	45.51	86.21	20.13
	MEMIT	51.07	35.48	95.50	3.32	46.35	32.18	95.27	3.98
	PROMPT	88.26	86.30	70.54	4.42	88.54	86.24	70.59	3.54
GPT-J-6B	FT	100.0	92.76	57.86	19.25	100.0	92.56	59.05	22.34
	ROME	99.20	83.01	70.14	14.16	99.21	81.94	71.07	13.27
	MEMIT	99.83	59.84	94.20	13.05	99.55	56.15	94.80	15.27
	PROMPT	88.41	86.42	69.10	-18.14	88.66	87.01	70.14	-17.70
LLaMA-2-7B-Chat	FT	100.0	89.60	84.53	0.66	100.0	89.07	85.49	0.44
	ROME	92.46	70.92	92.75	32.74	91.83	71.16	92.87	34.51
	MEMIT	91.18	78.47	89.89	30.75	90.92	77.92	91.37	35.62
	PROMPT	89.20	87.38	76.92	3.76	88.74	87.89	77.77	2.21
Mistral-7B-v0.1	FT	100.0	76.16	95.83	0.0	100.0	72.98	96.31	0.0
	ROME	96.47	76.11	93.99	10.62	96.56	76.00	94.37	11.06
	MEMIT	95.24	78.42	91.97	16.81	95.31	76.98	91.20	15.93
	PROMPT	90.22	88.65	81.31	0.44	90.17	88.68	82.75	0.22

Table 1: Main results of the baselines on the ConceptEdit. **Bold** results denote the best performance in each setting, while underlined results signify the second-best. \uparrow means the metric goes higher if it performs better. **Gen.** is the abbreviation of metric Generalization and **Inst.** is the abbreviation of metric Instance Change.

5 Experiment

5.1 Experimental Setting

Language models Four most prevalent open-source LLMs are used as base models for editing tasks. More precisely, we respectively utilize **GPT-J (6B)** (Wang and Komatsuzaki, 2021), **GPT2-XL (1.5B)** (Radford et al., 2019), **LLaMA-2-7B-Chat** (Touvron et al., 2023) and **Mistral-7B-v0.1** (Jiang et al., 2023) across various autoregressive models.

Methods We select four distinct methodologies commonly used for knowledge editing, namely: FT, ROME (Meng et al., 2022), MEMIT (Meng et al., 2023) and PROMPT. Detailed descriptions of these methods are presented in Appendix A.3.

Evaluation Metrics. To measure the impact of concept editing, we established a series of metrics, some following the setup by Yao et al. (2023):

Reliability. This metric straightforwardly measures the mean accuracy on a specific collection of pre-defined input-output pairs (x_e, y_e) :

$$\mathbb{E}_{x'_e, y'_e \sim \{(x_e, y_e)\}} \mathbb{1} \{ \operatorname{argmax}_y f_{\theta_e}(y | x'_e) = y'_e \} \quad (3)$$

Generalization. Considering that paraphrased sentences should be modified accordingly by editing, this metric gauges the average accuracy on equivalent neighbors $R(x_e, y_e)$:

$$\mathbb{E}_{x'_e, y'_e \sim R(x_e, y_e)} \mathbb{1} \{ \operatorname{argmax}_y f_{\theta_e}(y | x'_e) = y'_e \} \quad (4)$$

Locality. Noted as specificity within some literature, this metric is assessed based on the frequency at which the predictions of the post-edit model remain unchanged in out-scope neighbors $O(x_e, y_e)$:

$$\mathbb{E}_{x'_e, y'_e \sim O(x_e, y_e)} \mathbb{1} \{ f_{\theta_e}(y | x'_e) = f_{\theta}(y | x'_e) \} \quad (5)$$

Concept Specific Evaluation Metrics We also utilize **Instance Change** and **Concept Consistency** introduced in §3.2, revealing the instance level variation and semantic similarity of generated concept definition for conceptual knowledge editing.

5.2 Main Results

The experimental results depicted in Table 1 provide a quantitative assessment of various editing methodologies on concept editing task. 1) Firstly, it is noteworthy that all methods tested in larger scale models demonstrate high **reliability**, indicating their potential utility in addressing modifications at the concept-level definition. FT shows notable reliability which achieves 100 percent, but limits to smaller model GPT2-XL. 2) When shedding light on their adaptability to in-scope neighbors, there is still a discrepancy in performance; specifically, the results of **generalization** show a substantial decline when compared to reliability. Moreover, larger scale models demonstrate enhanced generalization capabilities post-editing relative to their smaller counterparts. Observations further reveal

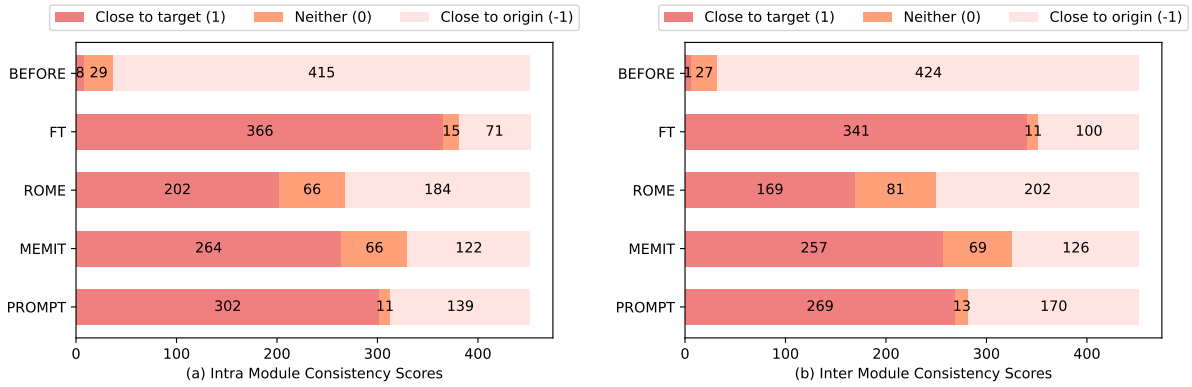


Figure 3: The results of the Concept Consistency employed on the **LLaMA-2-7B-Chat** across both intra and inter modules. This investigation entailed a comparison of generated sentences both pre-edited and post-edited via different editing methods. The evidence clearly indicates that FT surpasses other methodologies.

that method PROMPT stands out for its generalization and underscores its proficient understanding of conceptual context, even when prefix inputs are rephrased. 3) Additionally, the high **locality** results indicate that MEMIT exhibits the least impact on out-of-scope neighbors. Such performance implies that MEMIT operates with greater precision in locating and modifying the necessary parameters. 4) ROME leads to the clearest variations on **instance change**, with a notable impact observed in LLaMA where about one-third of the instance-to-category relationships are modified, emphasizing the instance-level alterations due to conceptual knowledge change. Conversely, the application of PROMPT within GPT-J is unsuccessful on instance change, as discussed in Appendix A.3.1.

5.3 Analysis

The gap between Reliability and Concept Consistency signals the necessity for concept specific evaluation metrics. Figure 3 presents the outcomes of the Concept Consistency, the novel metric established in §3.2. We choose LLaMA for its high-quality text generation, which surpasses the other models in producing responses with fewer meaningless repetitions and incoherent statements. Upon editing the conceptual knowledge, the FT outstrips other approaches on Concept Consistency, with 366 items more closely with the intended definitions as opposed to 71 items retaining their original state. PROMPT method also results in the desired change of generated definition text in over half of the test samples. **To demonstrate the alignment between GPT-4 evaluations and human preference within Concept Consistency, we select 50 cases from the entire set for manual evaluation,**

<p>Reliability 1.0 ✓</p> <p>[TARGET] set of episodes produced for a television series</p> <p>[GENERATE] set of episodes produced for a television series</p>	<p>Reliability 0.8571 ✓</p> <p>[TARGET] a sports person that plays curling</p> <p>[GENERATE] sportsperson that plays curling</p>
<p>Reliability 1.0 ✗</p> <p>[TARGET] the period of time when the sun is visible in the sky</p> <p>[GENERATE] the period during which organized baseball games are played</p>	<p>Reliability 0.6667 ✗</p> <p>[TARGET] that he or she is a person who has traveled to space</p> <p>[GENERATE] group of vascular plants</p>

Figure 4: Cases of Reliability Scores vs Generated Sentences. This Figure lists four representative cases that showcase the discrepancy.

which are included in Appendix A.3.2.

The generation function, which involves complex decoding mechanisms like probability normalization and sampling, creates an imperative for this evaluation, yielding text more diverse and coherent than selections from raw logit outputs. Typically, in instance-level editing, the generation remains consistent with the target entities. Although Reliability and the Concept Consistency draw upon the same input, their performance in actual assessments diverges. In Figure 4, even if reliability achieves a perfect score of 1.0, where each token predicted exactly corresponds to the matching next token in the target text, this does not ensure that the generated text as a whole is an exact match to the target text. Conversely, a slightly lower reliability score does not imply a complete failure. The reason is that each minor deviation during the generation process can cause the text to gradually diverge from the target. This indicates that when editing long texts, it is necessary to account for the uncertainties of the entire text generation process, notwithstanding the precision of individual token predictions.

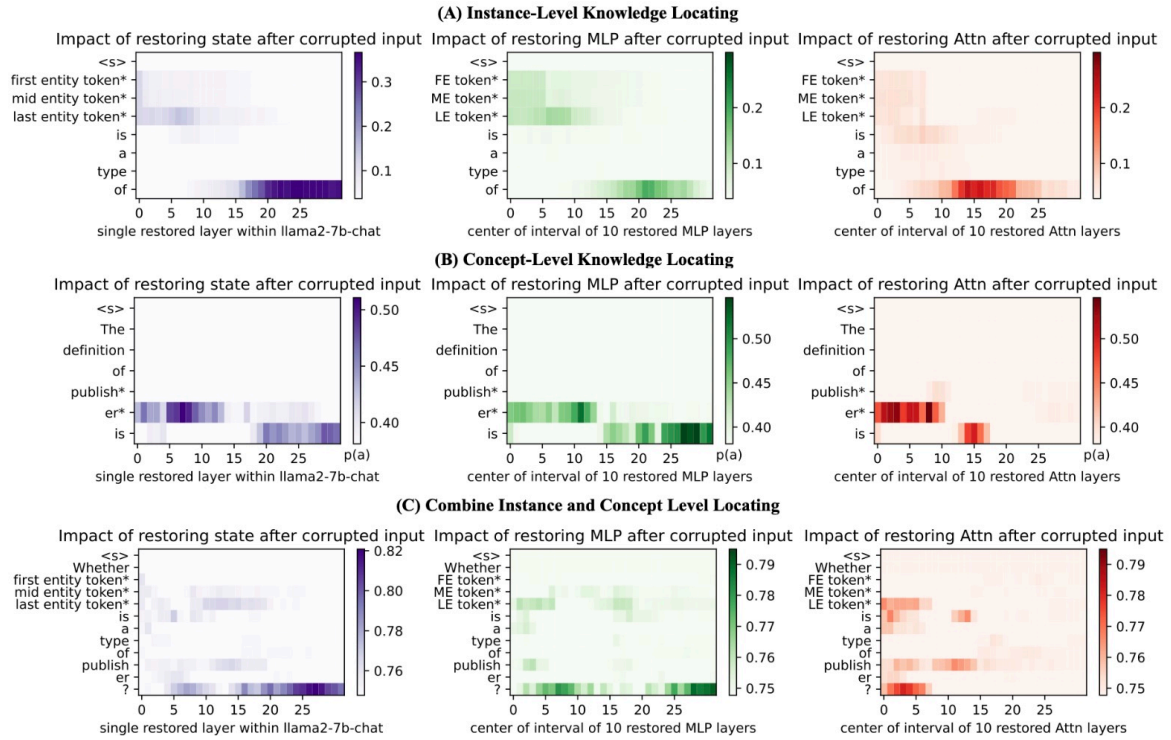


Figure 5: The conceptual and instancial knowledge locating in LLaMA-2-7B-Chat for the concept **publisher** and its corresponding instances by perturbing the input tokens.

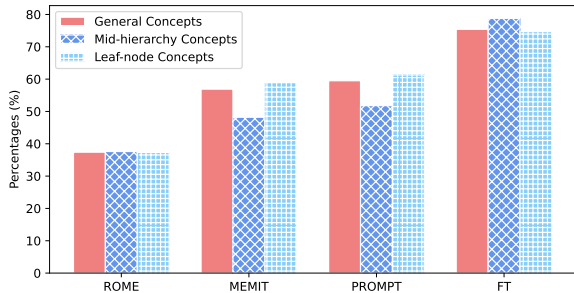


Figure 6: Considering concepts as tree-like structure, we assess the successful edits on mid-hierarchy and leaf-node concepts for more comprehensive analysis. The success rate is calculated by dividing the number of items get 1 in Concept Consistency by the total items.

The impact of concepts' structure on editing effects across superclasses but NOT hierarchy.

The comparison between intra and inter splits exposes another subtle yet important challenge in conceptual knowledge editing. Although results in Table 1 do not demonstrate significant differences in those metrics, Figure 3 illustrates a notable ease in Concept Consistency when the definition is substituted with a concept from the same superclass, likely owing to the pre-existing higher-level connection of two concepts. The findings indicate that mastering concepts spanning diverse superclasses

tends to be moderately more challenging. Note that old metrics used to quantify the editing performance might not be sensitive enough to capture these disparities linked to superclass structures. Meanwhile, even though some editing methods exhibit a slightly higher success rate on leaf-node concepts than mid-hierarchy ones in Figure 6, this minor gap does not substantially affect the overall effectiveness and there is no need for strategic adjustments based on hierarchical differences.

Generated sentence shows varying degrees of success in edits.

For the concept editing task, the ultimate goal pursued is for the model-generated sentences to match the target exactly. In practice, we encounter a variety of situations that reflect the model's varying degrees of success and failure in executing editing instructions. These categories and statements are detailed in Appendix A.4.

5.4 Locating Conceptual Knowledge in LLMs

To further explore the storage patterns and mechanisms (Wang et al., 2024a; Ferrando and Voita, 2024) of correlation between concepts and instances, we follow Meng et al. (2022), identifying neurons that have the strong causal effect in LLaMA-2-7B-Chat which has 32 transformer layers. The process of *Causal Tracing* specifically

involves three steps: *clean run*, *corrupted run*, *corrupted-with-restoration run*. It includes selecting certain specified tokens and recording the activation states before and after the addition of random noise, with the probability difference termed as the Indirect Effect (IE). Detailed formulas are provided in Appendix A.5. We design three prompt variations: “[instance] is a type of”, “The definition of [concept] is” and “Whether [instance] is a type of [concept]” to probe the instantial and conceptual knowledge, and then perturb the instance and concept tokens respectively. We carry out the analysis on the case concept “publisher” and average the hidden activation of all instances.

From Figure 5(A), there is strong causality at a ‘late site’ in last few layers at the final token, in line with earlier studies about instances. Decomposing the effects into Multilayer Perceptron (MLP) and Attention (Attn) lookups, the observation for instantial knowledge reveals that MLP contributions are predominant at the ‘early site’, coupled with Attn at the ‘late site’ as the model retrieves its concept. However, when locating conceptual knowledge as in Figure 5(B), it becomes apparent that both MLP and Attn module assume a heightened significance at ‘early site’. At ‘late site’, the MLP shows greater importance in last few layers but Attn shows in middle layers. This could potentially explain the effectiveness of ‘locate-and-edit’ strategies when modify the definition but not be as adept in achieving instance change. Results diverging from instantial knowledge may indicate the unique nature of concepts, with a high-dimensional generalization being more closely associated with attention in the early layers of the model.

Compared to the previous locating experiments, the association between conceptual knowledge and instantial knowledge may require the model to process in deeper exploration. Therefore, we integrate both instance and concept tokens within a singular sequence that serves as the input for causal tracing. From 5(C), although we can still observe that the last input token has the greatest influence on the entire response, the high IE performance in the attention layer has now shifted to the top ten layers. This result suggests that attention mechanisms in earlier layers are more integral to the processing and representation of this instance-to-concept relationship. To support the conclusions presented, we also carry out pertinent experiments on other cases, the details of which can be found in Appendix A.5.

6 Related Work

The current methods for knowledge editing are categorized into two main groups, those centered on preserving existing parameters and those entailing modification. The preservative methods incorporate explicit memory and prompting techniques to rectify model predictions. Examples include SERAC (Mitchell et al., 2022b), Mem-Prompt (Madaan et al., 2022) and IKE (Zheng et al., 2023). Some modify the Feed-forward Neural Network (FFN) layer, as exemplified by CaliNET (Dong et al., 2022), T-Patcher (Huang et al., 2023) and GRACE (Hartvigsen et al., 2023). Alternatively, the locate-and-edit approaches need to first locate the relevant neurons, followed by the adjustment of corresponding target parameters. Representative studies are KN (Dai et al., 2022), ROME (Meng et al., 2022), and MEMIT (Meng et al., 2023). Conversely, meta-learning utilize a hyper-network, a smaller network that generates the weights for layers in the main network, including KE (Cao et al., 2021), MALMEN (Tan et al., 2023) and MEND (Mitchell et al., 2022a).

To facilitate the research of knowledge editing, numerous datasets are exploring the potentialities and far-reaching effects. MQUAKE (Zhong et al., 2023) challenges model updates to factual changes using multi-hop questions, while RIPPLEEDITS (Cohen et al., 2024), DUnE (Akyürek et al., 2023) and ReCoE (Hua et al., 2024) expand the scope to encompass reasoning over subsequent facts. BAKE (Ma et al., 2023) assesses the reversibility of editing. Given the sequence of batch edits, Li et al. (2024c) identify paired edits that generate conflicts, and Li et al. (2023) examine dependency within internal logical constraints. Except for datasets which edit objects in triples, Wei et al. (2023) adopt a relation-centric perspective in edits. Hazra et al. (2024) investigate how the edits impact the safety. To the best of our knowledge, we are the first benchmark in LLMs for conceptual knowledge editing.

7 Conclusion

We introduce the conceptual knowledge editing task for LLMs, with a new benchmark ConceptEdit and evaluation metrics. From the experiments, we observe that existing editing methods, when modifying conceptual knowledge, have a very limited impact on the underlying instances; thus, stronger techniques and better understandings of concepts in LLMs are necessary for further research.

Limitations

Despite our best efforts, there remain several aspects that are not covered in this paper.

Models Due to computation resource constraints, we could not incorporate larger-scale models or experiment with a wider variety of architectures, such as Vicuna (Chiang et al., 2023), Qwen-72B (Bai et al., 2023), Mixtral-8×7B (Jiang et al., 2024). These models garner interest within the community and remain to be explored in the future study.

Task Settings About the scope of concept categorization presented herein, this paper delves into the realm of concrete concepts. However, it does not extensively cover the domain of abstract concepts, which encompass intangible entities or principles, such as rules and emotions (Wang et al., 2024b; Zou et al., 2023). Editing these broader concepts, with their intrinsic complexity and subtlety, is beyond the confines of the current discussion and remains further research.

Mechanism This paper primarily analyzes the concept location and editing mechanisms within LLMs. The investigation into how LLMs learn and represent various concepts and entities, as well as the establishment of concept hierarchies, remains cursory. These aspects are yet to be fully understood and warrant more comprehensive study.

Ethics Statement

This study adheres strictly to the most rigorous ethical standards and best practices in research. All data utilized are extracted from datasets that are available to the public, thereby ensuring no usage of any proprietary or sensitive information. As a result, this research is free from any ethical concerns.

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A Appendix

A.1 Templates

Here we numerates a variety of templates employed within our experimental framework.

Template for Instance Change

Whether FrancoAngeli belongs to category publisher? Yes
Whether And Other Stories belongs to category people? No
Whether [INSTANCE] belongs to category [CONCEPT]?

Table 2: Template for Instance Change

Table 2 shows the few-shot prompt used both before and after the edits. As introduced in Section 3.2, a positive response yes equates to a score of 1 in Instance Change. Upon revising the definitions of pertinent concepts, a shift in the instance-to-category relationship is anticipated. Thus, a negative response no from the model post-editing signifies that the relation is altered. For instance, when $I_\theta(C \in t) = 1$ with C representing concept ‘publisher’ and initial definition, and t referring to ‘Victoria University Press’. Ideally, $I_{\theta_e}(t \in C^*) = 0$, because the conceptual knowledge is changed, the post-edited model no longer associates ‘Victoria University Press’ with the concept ‘publisher’.

Template for Concept Consistency

Prediction sentence: [PREDICTION]

Sentence A: [TARGET].
Sentence B: [GROUND].

Check the prediction sentence and Give a score from -1 to 1:
Score 1: close meaning to sentence A
Score 0: neither relevant to A nor B
Score -1: close meaning to sentence B

Output format is {Score:{}, Reason:{}}

Table 3: Template for Concept Consistency

Table 3 delineates the structured template utilized for the *Concept Consistency*, which acts as an input for the GPT-4 evaluator. Through qualitative analysis, the *Concept Consistency* classifies the generated sentences into three discrete scores. The adoption of a relative comparison, rather than assigning an absolute value, acknowledges the proficiency of the evaluator that is preliminarily verified to align more closely with human judgment.

Table 4 enumerates twenty restructured exemplars derived from GPT-4 responses as the equivalent neighbors. Equivalent neighbor means another sentence expressing similar semantic meaning of

Twenty Restructured Exemplars

The meaning of [CONCEPT] can be described as
In essence, [CONCEPT] is defined as
To put it simply, [CONCEPT] refers to
[CONCEPT] is characterized by the following definition
A concise explanation of [CONCEPT] is
Defined as such, [CONCEPT] can be understood as
When we talk about [CONCEPT], we mean
In simple terms, [CONCEPT] is defined as
The definition ascribed to [CONCEPT] is
To clarify, [CONCEPT] is defined by
[CONCEPT] is essentially defined as
Describing [CONCEPT], we can say
The definition assigned to [CONCEPT] is
In the context of [CONCEPT], we define it as
Putting it in words, [CONCEPT] is defined as
When we refer to [CONCEPT], we are talking about
In defining [CONCEPT], we consider it as
The characterization of [CONCEPT] involves
Defining [CONCEPT] boils down to
It can be stated that [CONCEPT] is defined as

Table 4: Templates for equivalent neighbors

descriptor x , used in metric Generalization. Employing GPT-4 to reformulate “*The definition of [CONCEPT] is*” facilitates the generation of equivalent neighbors varied and increased fluency.

Template for Method PROMPT

Prompt:
Definition of [CONCEPT]: [DESCRIPTOR Y]

Example:

Pre-Editing: The definition of military person is *someone who rides horses in horse racing or steeplechase racing*.

Post-Editing: Definition of military person: someone who rides horses in horse racing or steeplechase racing.
The definition of military person is *someone who rides horses in horse racing or steeplechase racing*.

Table 5: Template for Method PROMPT

The PROMPT method utilizes a prefix sentence as the prompt used for inference in LLM to instruct (edit) the output. Table 5 presents the template employed by the PROMPT method for editing, along with an illustrative example showing the difference between pre-editing and post-editing sentences in a practical application. This *Prompt* portion is what constitutes the PROMPT method. Furthermore, in the computation of metric *Instance Change*, the *Prompt* prefix is positioned antecedent to the few-shot demonstrations.

A.2 Data Distribution

Table 6 introduces the statistics of ConceptEdit dataset that describes its composition.

Property	Number
Number of <i>Concepts</i>	452
Number of <i>Instances</i>	8,767
Number of <i>Superclasses</i>	22
Average tokens length of <i>Description</i>	12.95
Max/Min tokens length of <i>Description</i>	45 / 3

Table 6: ConceptEdit Dataset Statistics

Figure 7 illustrates that the predominant super-class distribution of ConceptEdit bears a resemblance to origin ontology. When dividing between intra and inter modules, we randomly pick a replacement concept either from the same group or a different one. For categories with fewer than five concepts, we make selection from the entire set.

Figure 8 presents a comparison of the length of tokens between the prior editing dataset zsRE and our dataset. At the same time, Table 8 supplements our dataset and CounterFact dataset in terms of content differences. This is to illustrate the distinction between the conceptual knowledge editing task and the instance-level factual editing.

Drawing on ontology datasets, our study utilizes the knowledge from DBpedia as performed by Wu et al. (2023). This initial phase involves the careful retrieval of a total of 783 distinct classes, each representing a specific concept within the ontology. The dataset not only retains the hierarchy of super-classes but also harnesses SPARQL to interrogate 20 instances chosen at random via the `type_of` relation. OntoProbe provides a solid foundation with elements such as concept names and their instances. However, to integrate it into proposed concept editing task, we recognize that substantial effort is required to adapt the dataset accordingly. Table 9 demonstrates that our task with the OntoProbe dataset is entirely different.

A.3 Experiment Details

We utilize four editing baselines on concept editing task, which are detailed as following:

Finetune (FT) updates parameters by gradient descent for a single MLP layer and applies early stop strategy to constrain the modifications in the weights. Here, we adopt FT-M in EasyEdit (Wang et al., 2023c) which finetune a single layer by cross-entropy loss optimization.

ROME (Meng et al., 2022) envisages the MLP module as a key-value storage, leverages causal mediation analysis to locate the edit area, and update a whole FFN layer to encode new knowledge.

MEMIT (Meng et al., 2023) adopts the localization techniques in ROME and uses explicitly computed parameter updates to embed new memories across multi-layers.

PROMPT is well known that a well-designed prompt can effectively guide the behavior of LLMs, demonstrating a strong ability to learn from context. The prompt used here is shown in Table 5.

The experimental procedures undertaken in this study are underpinned by the utilization of the tool **EasyEdit**² (Wang et al., 2023c). Moreover, the selection of hyper-parameters adheres to the default configurations as established. Taking into account the scale of *LLaMA-2-7B-Chat* and *Mistral-7B-v0.1*, we conduct our experiments on an A800 GPU within a local computing environment, for current editing methods involving more than just inference.

It is imperative to note that in concept editing task, the editing manipulation is performed dependently, targeting only the specified descriptor (x_e, y_e) with a single edit at a time not sequentially. After the evaluation is completed for each sample, the edited model is reset to its original state before the edit. This ensures that each editing operation is isolated and does not affect subsequent edits, allowing for a controlled assessment of each individual modification to the conceptual knowledge.

A.3.1 Special Circumstances of Instance Change on GPT-J

As introduced in § 4.2, we delegate a mandate to LLMs to generate an alternative instance that is expected to be within the confines of the model’s existing corpus of knowledge to ensure continuity. This step exists uncertainty, as there is a possibility that the newly generated instance might not satisfactorily address the query in Table 2 before editing. Despite our efforts to refine the demonstrations and retain an appropriate instance, we cannot assure that the function G_θ will always yield score 1. The negative numbers in Table 1 show shortage of GPT-J when recognizes such instance-to-category relationship. It is somewhat peculiar to discover certain instances that initially fail to pass the identification process, yet post-editing, they oddly begin to affirm the query yes, which result in the negative number recorded in method PROMPT. Anyhow, such situation is not commonly found in the other LLMs’ performance in our experiment.

²<https://github.com/zjunlp/EasyEdit>

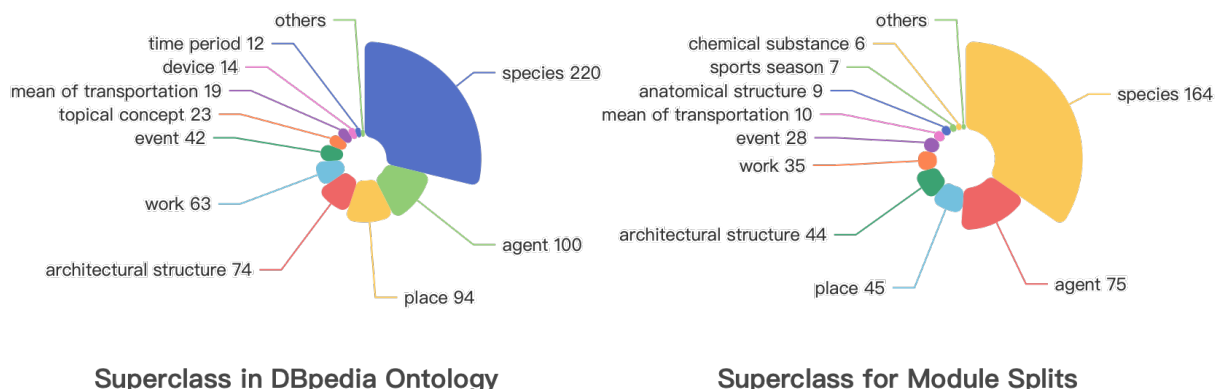


Figure 7: Statistics of superclass distribution. Considering DBpedia Ontology exhibits a hierarchical and tree-like arrangement, we category each concept based on its highest-level node. The left panel illustrates the frequency distribution among the original **DBpedia Ontology** concepts, whereas the right panel depicts the distribution of selected concepts in **ConceptEdit**.

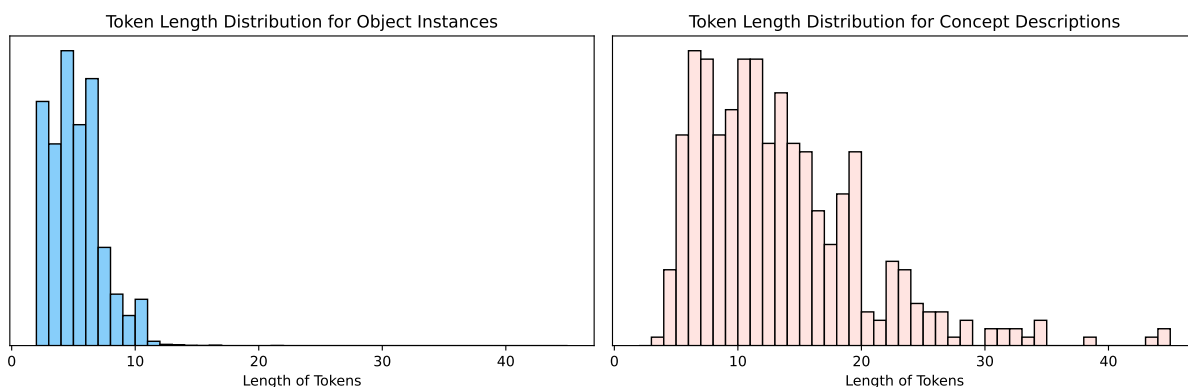


Figure 8: Comparison of tokens length tokenized by **LLaMA-2-7B-Chat** for editing tasks. The left table presents token lengths for the **zsRE** dataset, showing that most lengths fall below 10. On the right side, the table illustrates that the **ConceptEdit** dataset features tokens of greater length, encompassing a broader range of length. **zsRE** is commonly employed in instance-level editing, focusing on specific entities, while **ConceptEdit** involves editing descriptions for concepts, which tend to be more extensive.

Category	Case in generated sentence
Case A	group of people that play team handball. [TARGET]: group of people that play team handball. [ORIGIN]: facility that makes wine.
Case B	100% pure chemical compounds that are composed of two or more different elements. [TARGET]: pure chemical substance consisting of two or more different chemical elements. [ORIGIN]: biomolecule consisting of chains of amino acid residues.
Case C	the process of creating a detailed plan for the production of a radio or television program. [TARGET]: organization responsible for production and transmission of radio and television programs. [ORIGIN]: business entity formed by one or more lawyers to engage in the practice of law.
Case D	an individual who has the potential to participate in the sport of beach volleyball at a competitive level. [TARGET]: prospective recipient of an award or position. [ORIGIN]: sports person who plays beach volleyball.
Case E	a film that was released in 1945, directed by Michael Curtiz and starring Tom Neal, Ann Sheridan, and Edward G. [TARGET]: minor planet of the inner Solar System; not a comet. [ORIGIN]: camp in which people are imprisoned or confined, commonly in large groups, without trial.

Table 7: Diverse scenarios showcasing the model’s range of outcomes, from successful editing executions to cases of failure. [TARGET] denotes the revised description. [ORIGIN] refers to the initial recognition prior to editing.

ConceptEdit		CounterFact	
id	1	case_id	8
concept_name	military person	prompt	What is the twin city of Wellington? It is
concept_def	those who serve as part of an organized armed military force	target_new	Sheffield
top_superclass	species	ground_truth	Sydney
instances	["Ronald Reid-Daly", "Charles Augustus Hilton", "27th Indiana Infantry Regiment", "Spartaco Schergat", "Charles Corcoran", "Franois Claude Amour, marquis de Bouill", "Clyde A. Vaughn", "Earle Wheeler", "Joe McCarthy", "Central African Republic Civil War", "Andrew Mathews", "Nikolaus Heilmann", "Ahmed Abdel Rahman Nasser", "Reed McKinley Chambers", "Wallace Lawler", "Clarence Tan", "Louis Charles mile Gibon-Guilhem", "Manshuk Mametova", "Moshe Tzadok", "John F. G. Howe"]	rephrase_prompt	People in Wellington's twin city speak the language of
QID	Q47064	locality_prompt	What is the twin city of Chicago? It is
module_intra	{"replace_from_concept": "jockey", "replace_def": "someone who rides horses in horse racing or steeplechase racing" }	locality_ground_truth	Sydney
module_inter	{"replace_from_concept": "settlement", "replace_def": "place of any size, in which people live" }		
locality_prompt	The definition of bacteria is		
locality_answer	domain of micro-organisms		

Table 8: The existing knowledge editing datasets differ significantly from ours; the current factual editing datasets are instance-level and lack exploration at the level of conceptual knowledge. We identify this gap during our preliminary research and thus transform an ontology dataset to create ConceptEdit. We list the differences between ConceptEdit and the commonly used factual editing dataset, CounterFact.

ConceptEdit		OntoProbe	
id	1	id	1
concept_name	military person	rdfs:label	military person
concept_def	those who serve as part of an organized armed military force	rdfs:Class	http://dbpedia.org/ontology/MilitaryPerson
top_superclass	species	rdfs:subClassOf	["person", "animal", "eukaryote", "species"]
instances	["Ronald Reid-Daly", "Charles Augustus Hilton", "27th Indiana Infantry Regiment", "Spartaco Schergat", "Charles Corcoran", "Franois Claude Amour, marquis de Bouill", "Clyde A. Vaughn", "Earle Wheeler", "Joe McCarthy", "Central African Republic Civil War", "Andrew Mathews", "Nikolaus Heilmann", "Ahmed Abdel Rahman Nasser", "Reed McKinley Chambers", "Wallace Lawler", "Clarence Tan", "Louis Charles mile Gibon-Guilhem", "Manshuk Mametova", "Moshe Tzadok", "John F. G. Howe"]	is rdfs:type of	["Ronald Reid-Daly", "Charles Augustus Hilton", "27th Indiana Infantry Regiment", "Spartaco Schergat", "Charles Corcoran", "Franois Claude Amour, marquis de Bouill", "Clyde A. Vaughn", "Earle Wheeler", "Joe McCarthy (RCAF officer)", "Central African Republic Civil War (2012-present)", "Andrew Mathews", "Nikolaus Heilmann", "Ahmed Abdel Rahman Nasser", "Reed McKinley Chambers", "Wallace Lawler", "Clarence Tan", "Louis Charles mile Gibon-Guilhem", "Manshuk Mametova", "Moshe Tzadok", "John F. G. Howe"]
QID	Q47064		
module_intra	{"replace_from_concept": "jockey", "replace_def": "someone who rides horses in horse racing or steeplechase racing" }		
module_inter	{"replace_from_concept": "settlement", "replace_def": "place of any size, in which people live" }		
locality_prompt	The definition of bacteria is		
locality_answer	domain of micro-organisms		

Table 9: Here we showcase a comparison of ConceptEdit and OntoProbe example. Our dataset introduces concepts and applies them to editing tasks, whereas OntoProbe focuses more on exploring the structure of ontological knowledge. For example, our task needs to redefine those concepts, which entails the gathering of definition contexts from WIKIDATA. Furthermore, to employ calculation of editing metrics, we construct equivalent neighbors and out-of-scope neighbors needed. Those efforts are detailed in the paper section 4.2.

A.3.2 Manual and GPT-4 Evaluation on Metric Concept Consistency

Concept Consistency	GPT-4	Human
-1: close to origin	19	16
0: neither	6	9
1: close to target	25	25
total number	50	50

Table 10: Comparison of GPT-4 Scores vs. Human Scores on metric Concept Consistency.

To illustrate the effectiveness of using the GPT-4 API as an automatic evaluator for metric Concept Consistency and to verify the extent to which GPT-4 evaluation of semantic similarity aligns with human evaluation, we sample 10 examples each from the pre-edited output and the outputs edited by four different editing methods, resulting in a total of 50 cases for comparison between GPT-4 and human evaluation results. The scoring criteria for the human evaluation are the same as those designed for the GPT-4 evaluation. Also, a graduate student assists us with the human evaluation. The results, presented in Table 10, indicate that out of all 50 samples, only 3 records differ between GPT-4 and the human judges, with errors mainly occurring in the judgment of scores -1 and 0. However, for scores of 1 (that is, close to the target), all judgments are consistent. This implies that using GPT-4 as an automatic evaluator is reliable for metric Concept Consistency.

A.4 Case in Generated Sentence

Table 7 exhibits five representative cases of the generated sentences, showcasing the varying levels of success and failure in carrying out the edits.

CASE A: Ideal Successful Edit In the best scenarios, the edited Sentence A perfectly aligns with the target sentence, with every word matching without any discrepancies. These are the desired outcomes.

CASE B: Consistent Meaning but Not a Perfect Match In some cases, the edited sentence, while not identical to the target sentence, conveys a similar core meaning. This could involve the use of synonyms or synonymous expressions. In human reviews, such cases are considered acceptable because they retain the main content.

CASE C: Partially Consistent but Differing in Meaning There are also cases, where the edited sen-

tence partially overlaps with the target sentence, but does not convey the exact same meaning, possibly differing in the explanation of certain key information. Although the result is not completely accurate, it is closer to the target than before editing, thus providing a point that is worth more attention in future research.

CASE D: Edit Failures But Original Meaning Maintained In cases of editing failure, this is a typical example. In these situations, although the editing task was not successful, the model-generated sentences maintained their original semantic content without any substantive change.

CASE E: Neither Target Nor Original Meaning Finally, we also discover special cases, a kind of editing failure where the generated sentence neither matches the editing target nor retains the original meaning. This situation is different from Case B because it does not have any consistency with the target nor does it maintain the meaning before editing, presenting an entirely unexpected result that also warrants further analysis and study.

A.5 Knowledge Locating

We introduce the knowledge locating details which is introduced by Meng et al. (2022). Given a model f_θ and an input text $X = \{x_i | i \in [1, N]\}$, where N is the number of input tokens, and we denote the tokens to be perturbed as x_t , which refer to the subject entity.

Clean run involves a normal forward process $f_\theta(X)$, and then saves the hidden activations $\{h_i^l | i \in [1, N], l \in [1, L]\}$, here L indicates the layer number of model f_θ .

Corrupted run. Then we conduct the process of corrupting. Specifically, after embedding the tokens as $\{h_i^0 | i \in [1, N]\}$, we directly add noise to the entity tokens x_t before they are fed into the model, denoted as $h_t^0 := h_t^0 + \epsilon$. Here $\epsilon \sim N(0, \nu)$, and we follow previous work (Meng et al., 2022) to select ν to be 3 times larger than that of the empirical standard deviation of embeddings. In this way, we obtain the corrupted hidden activations $\{h_{i*}^l | i \in [1, N], l \in [1, L]\}$.

Corrupted-with-restoration run hooks the model f_θ and iteratively attempts to restore the corrupted hidden state at each token and each layer to the clean state without intervening the future computations.

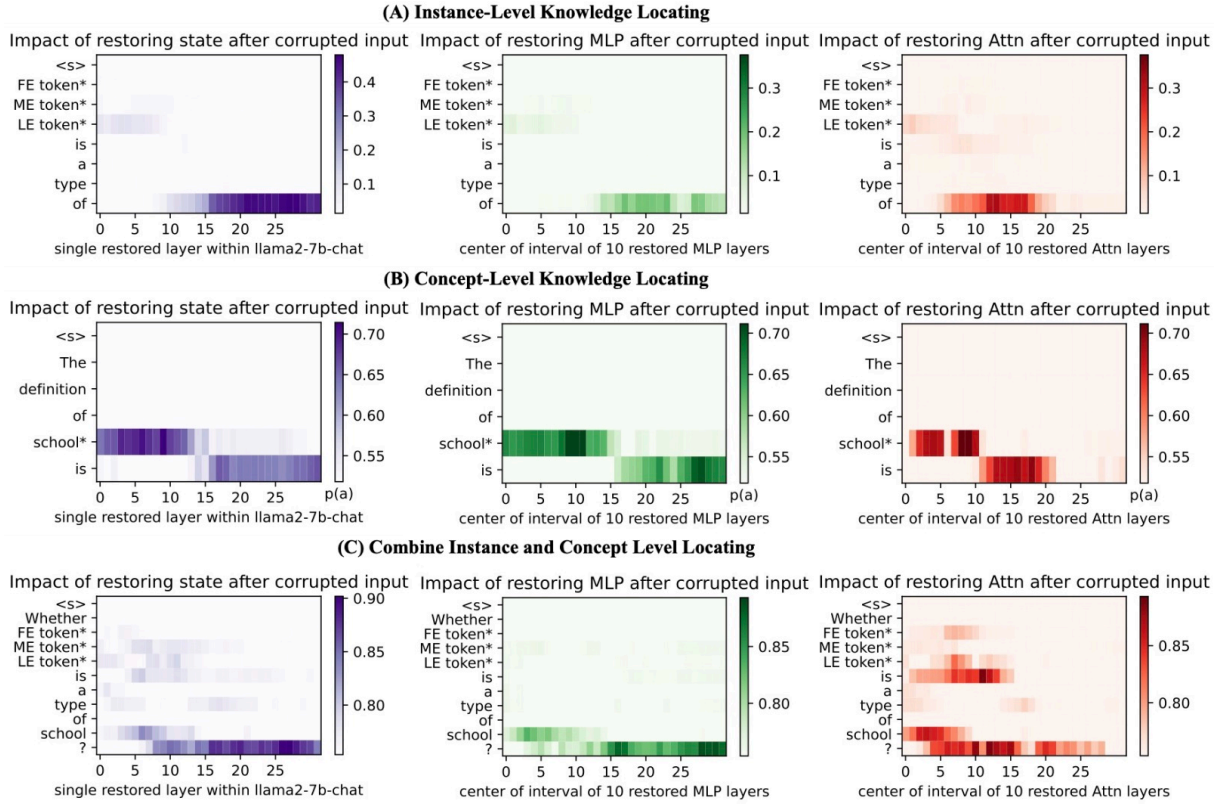


Figure 9: Case of casual tracing on concept “school” shows similar appearance of the lookup patterns. As our previous study discussed, the conclusion is basically in line with case *publisher*.

Indirect Effect. The final probability on target tokens of the three runs above is defined as \mathbb{P} , \mathbb{P}_* and $\mathbb{P}_*^{clean} h_i^l$. The indirect effect (IE) of a particular hidden state h_i^l is defined as $\text{IE} = \mathbb{P}_*^{clean} h_i^l - \mathbb{P}_*$.