

# REARANK: Reasoning Re-ranking Agent via Reinforcement Learning

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## Abstract

We present REARANK, a large language model (LLM)-based listwise reasoning reranking agent. REARANK explicitly reasons before reranking, significantly improving both performance and interpretability. Leveraging reinforcement learning and data augmentation, REARANK achieves substantial improvements over baseline models across popular information retrieval benchmarks, notably requiring only 179 annotated samples. Built on top of Qwen2.5-7B, our REARANK-7B demonstrates performance comparable to GPT-4 on both in-domain and out-of-domain benchmarks and even surpasses GPT-4 on reasoning-intensive BRIGHT benchmarks. These results underscore the effectiveness of our approach and highlight how reinforcement learning can enhance LLM reasoning capabilities in reranking. The code is available <https://github.com/lezhang7/Rearank>.

## 1 Introduction

Information retrieval (IR) is a fundamental component of intelligent systems, forming the basis for accessing, organizing, and reasoning over information across different modalities (Radford et al., 2021; Zhang et al., 2023; Li et al., 2025a,b; Chen et al., 2025; Fu et al., 2025; Huang et al., 2025). Modern IR systems (Reimers and Gurevych, 2019, 2020; Wang et al., 2021; Formal et al., 2021; Wei et al., 2025) typically follow a two-stage approach: initial retrieval (e.g., fast lexical methods (Robertson et al., 2009)) to gather candidates, followed by reranking for fine-grained prioritization of relevant results. This two-stage process is particularly crucial for Retrieval-Augmented Generation systems (Lewis et al., 2020; Borgeaud et al., 2022; Zhang et al., 2023; Liu et al., 2024), where accurate retrieval and effective reranking of context passages significantly impact generated output quality.

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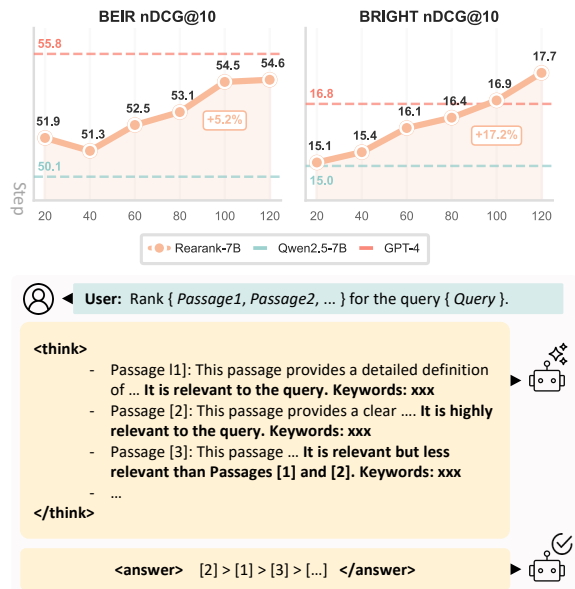


Figure 1: (Top) Average rerank results on popular benchmarks (over BM25 top 100), the performance improves with RL training; (Bottom) REARANK inference example. The agent provides the reasoning and final ranking of all passages, unlike current agents (Sun et al., 2023; Pradeep et al., 2023b) that only output the final answer.

Recent advances in large language models (LLMs) (Yang et al., 2024, 2025; Achiam et al., 2023; Zhou et al., 2025; Dao et al., 2022) have shown strong promise for this reranking phase (Sun et al., 2023), particularly through their use as *reranking agents* that rely on direct outputs rather than internal states (e.g. *logits*). This paradigm, exemplified by zero-shot prompting methods (Sun et al., 2023; Ma et al., 2023; Zhuang et al., 2024), offers significant deployment flexibility, especially in model-as-a-service scenarios. However, effectively adapting LLMs specifically as reranking agents presents several key challenges: (i) LLMs are not inherently optimized for ranking objectives, and crucially, current zero-shot methods do not learn from the interaction signals generated during the reranking process; (ii) Achieving com-

petitive performance often necessitates supervised fine-tuning, a process severely constrained by the scarcity and high cost of acquiring high-quality labeled ranking data (Sun et al., 2023); (iii) The decision-making processes within these models frequently lack transparent and interpretable reasoning, which limits explainability and fails to leverage test-time scaling properties of LLMs; (iv) State-of-the-art reranking agents frequently depend on large, often proprietary models (e.g., GPT-4) or face significant challenges in local deployment. This dependency on large models incurs substantial computational costs and significant inference latency (e.g., reranking 20 passages with reasoning process using DeepSeek-R1 (Guo et al., 2025) via API takes around 90-120 seconds).

In this work, we propose REARANK, the first reasoning *listwise* reranking agent. REARANK’s optimization for listwise reranking with explicit reasoning is incentivized using reinforcement learning (RL). This approach effectively leverages the rich, order-based signals inherent in listwise reranking. To address the significant data scarcity challenge typically associated with training listwise models, we introduce a data augmentation pipeline capable of generating extensive listwise ranking sets from a remarkably small seed of only 179 annotated queries. At inference, REARANK generates explicit, interpretable reasoning for each ranking step, as shown in fig. 1, enabling test-time scaling. Built upon the principle of injecting strong reasoning capabilities into a compact model, REARANK operates with low operational cost. The combination of its practical model size and listwise reranking strategy enhances inference efficiency by minimizing LLM calls, thereby facilitating local deployment.

Our experimental results demonstrate REARANK’s effectiveness: it significantly surpasses baseline models and achieves performance comparable to strong models like GPT-4 and the recent powerful reasoning model Qwen3-32B on standard and out-of-domain benchmarks. Notably, REARANK even surpasses strong GPT-4 performance on reasoning-intensive tasks, highlighting its advantages in combining reasoning with practical efficiency, as summarized in fig. 1.

Our main contributions are threefold: (i) We introduce REARANK, a novel reasoning-based reranking agent based on the listwise reranking strategy that effectively integrates explicit reasoning capabilities into the reranking process. We formalize the reranking problem in RL frame-

work, and propose a data synthesis method requiring only 179 annotated queries, and a new reward model leveraging ranking information for training, enabling efficient RL training of REARANK; and (ii) REARANK achieves significant performance improvements over strong baselines and matches or surpasses results from competitive models like GPT-4 and strong reasoning model Qwen3, particularly on reasoning-intensive tasks, while offering substantially improved inference efficiency due to its compact model size. (iii) We provide a comprehensive analysis on reasoning transferability and examining the relationship between reasoning length and final ranking performance to better understand the role of reasoning in reranking.

## 2 Related Work

**Large Reasoning Models** Recent advancements in LLMs have yielded increasingly sophisticated reasoning capabilities (Liu et al., 2025; Wu et al., 2025), often emerging with scale (Wei et al., 2022a; Kojima et al., 2022). Techniques like Chain-of-Thought prompting (Wei et al., 2022b) and its variants (Kojima et al., 2022; Wang et al., 2022) further enhance these skills by enabling explicit reasoning processes. Beyond prompting, training methods like RL (Guo et al., 2025) are used to incentivize long CoT reasoning; models such as Deepseek-R1, OpenAI o1, and o3 leverage RL for enhanced reasoning, showing general task improvements. These developments enable LLM application in complex domains like math problems and planning. Our work applies these advanced reasoning capabilities to reranking.

**LLMs for Re-ranking** LLMs are increasingly being used for reranking, moving beyond traditional feature-based models (Zhang et al., 2024b; Lee et al., 2024; Ma et al., 2024a; BehnamGhader et al., 2024; Sachan et al., 2022). Approaches range from pointwise (Liang et al., 2022), pairwise (Qin et al., 2023), setwise (Zhuang et al., 2024) to listwise methods (Ma et al., 2023; Sun et al., 2023; Pradeep et al., 2023b). While few-shot/zero-shot prompting was explored, supervised fine-tuning on ranking data shows further gains (Pradeep et al., 2023b,a). Building on this, our work proposes a novel RL approach without cold start for training a listwise LLM reranker, focusing on robust performance and reasoning capabilities, especially in out-of-domain and reasoning-intensive scenarios.

A concurrent work (Zhuang et al., 2025) also

trains an LLM as a *setwise reranker* using RL. It simplifies the task to finding the *single most relevant passage index*, relying on a sparse text-matching binary reward signal. This signal lacks the rich, order-based information present in listwise ranking, which consequently necessitates extensive training data. Furthermore, setwise inference is highly inefficient as it *ranks only one passage at a time*, unlike our listwise method which *reranks an entire passages simultaneously* as shown in fig. 2. Therefore, we adopt the listwise reranking strategy.

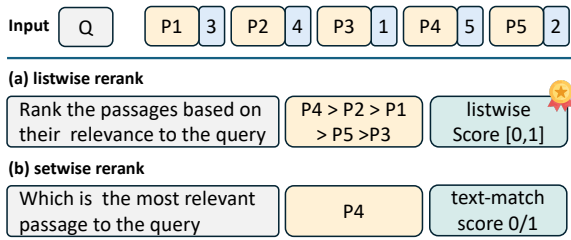


Figure 2: **Listwise vs. Setwise Reranking.** Setwise reranking yields binary scores (0 or 1); listwise reranking offers richer, continuous scores between 0 and 1.

### 3 Method

#### 3.1 Listwise Re-ranking Agent

Given a query  $q$  and an initial set of  $n$  retrieved passages  $P = (p_1, \dots, p_n)$ , the objective of reranking is to find the optimal permutation (ranking) of these passages. This can be formally expressed as maximizing a ranking quality score:

$$\max_{\sigma \in K_n} r(\{p_{\sigma(1)}, p_{\sigma(2)}, \dots, p_{\sigma(n)}\}), \quad (1)$$

where  $K_n$  is the set of all possible permutations of the passages  $P$ ,  $\sigma$  represents a specific permutation (a ranking),  $p_{\sigma(i)}$  is the passage located at rank  $i$  in the ranking defined by  $\sigma$ , and  $r$  is a scoring function that measures the quality of the entire ranked list.

Listwise reranking methods (Sun et al., 2023; Ma et al., 2024b; Pradeep et al., 2023b) reorder subsets of passages using a sliding window. This is necessary due to the limited context length of LLMs, preventing simultaneous processing of all passage at a time. Given an initial ranking  $\tau$  over passages  $P$ , an LLM-based permutation function  $h$  (see fig. 2) is applied to a window of size  $w$  starting at index  $i$  to determine the reordering within the final ranking  $\sigma$  based on relevance to  $q$ :

$$\begin{aligned} & \{p_{\sigma(i)}, \dots, p_{\sigma(i+w-1)}\}, \\ & = h(\{p_{\tau(i)}, \dots, p_{\tau(i+w-1)}\}, q), \end{aligned} \quad (2)$$

The final top-k list is constructed by iteratively applying  $h$  using a sliding window that processes the whole passages list, often from the end towards the beginning. This window is typically shifted by  $w/2$  steps to create overlap, resulting in approximately  $O(2n/w)$  total LLM calls for  $n$  passages and offering significant efficiency advantages.

#### 3.2 RL for Listwise Re-ranking

A common mathematical framework for reinforcement learning is the Markov Decision Process (MDP), formally defined as a tuple  $(S, A, T, r, \gamma)$ . Here,  $S$  represents the state space,  $A$  is the action space,  $T : S \times A \times S \rightarrow [0, 1]$  denotes transition probabilities,  $r : S \times A \rightarrow \mathbb{R}$  is the reward function, and  $\gamma \in [0, 1)$  is the discount factor.

In the context of passage reranking, we model the process as an MDP where the agent is our LLM policy  $\pi_\theta$ . The environment is defined by the query  $q$  and an initial ranking  $\tau$  over a set of passages  $P = (p_1, \dots, p_n)$ . The state space  $S$  is defined by the current ranking of passages and the query, specifically  $\mathcal{S} = (\{p_{\tau(1)}, \dots, p_{\tau(n)}\}, q)$ . The action space  $A$  corresponds to the set of possible permutation functions  $h$  that the LLM can apply to the current state. The transition function  $T$  models how actions lead to new states (rankings). The reward function  $r$  quantifies the quality of a reranking action based on relevance metrics, providing feedback to the agent.

We train  $\pi_\theta$ , an LLM fine-tuned to generate an output sequence  $G$  consists of reasoning process and a new permutation  $\sigma_\theta$  based on the input  $x = (\{p_{\tau(1)}, \dots, p_{\tau(n)}\}, q)$ . The learning objective is to maximize the expected reward:

$$\theta^* = \arg \max_{\theta} \mathbb{E}_{(q,P) \sim \mathcal{D}} [r(\sigma_\theta)],$$

where  $\mathcal{D}$  is the data distribution.

Inspired by DeepSeek-R1 (Guo et al., 2025), we employ the simple Grouped Policy Optimization (GRPO) algorithm. Training involves sampling a group of output sequences  $G = \{o_1, o_2, \dots, o_G\}$  for each input  $x$  with the system prompt. A rule-based reward  $r_i$  is computed for each output sequence  $o_i$  and normalized within the group  $G$  to yield advantages  $\hat{A}_i$ . Following DeepSeek-Math’s (Shao et al., 2024) approach using current policy samples, the token-level objective is:

$$\mathcal{J}_{\text{GRPO}}(\theta) = -\frac{1}{|G|} \sum_{i=1}^{|G|} \frac{1}{|o_i|} \sum_{t=1}^{|o_i|} l_{i,t}, \quad (3)$$

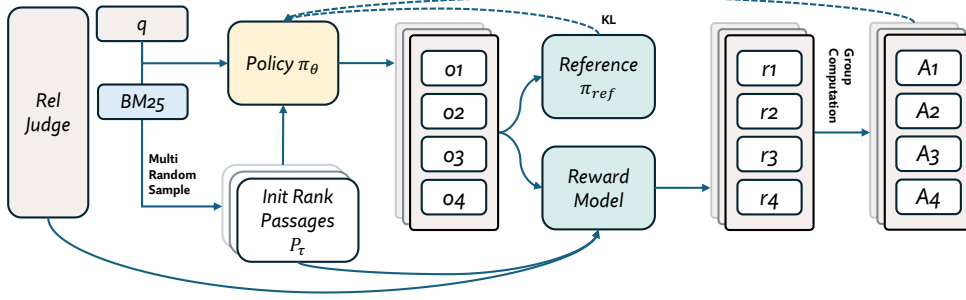


Figure 3: Pipeline of the proposed GRPO-based RL framework for listwise passage reranking. Training utilizes data generated by sampling multiple passage sets per query and evaluating them with consistent relevance judgments.

where

$$l_{i,t} = \frac{\pi_{\theta}(o_{i,t} | x, o_{i,<t})}{[\pi_{\theta}(o_{i,t} | x, o_{i,<t})]_{\text{no grad}}} \hat{A}_{i,t} - \beta \mathbb{D}_{\text{KL}}[\pi_{\theta}(\cdot | x, o_{i,<t}) || \pi_{\text{ref}}(\cdot | x, o_{i,<t})]. \quad (4)$$

Here,  $|G|$  is the number of output sequences sampled from current policy  $\pi_{\theta}$  given input  $x$ ,  $|o_i|$  is sequence length, and  $l_{i,t}$  is the per-token loss.  $\pi_{\theta}(o_{i,t} | x, o_{i,<t})$  is the policy probability for token  $o_{i,t}$  given  $x$  and preceding tokens  $o_{i,<t}$ , with  $[\cdot]_{\text{no grad}}$  denoting gradient detachment. The token-wise advantage  $\hat{A}_{i,t}$  is derived from outcome supervision, calculated as the Z-score of the instance reward  $r_i$  relative to the batch rewards  $\mathbf{r}$ :  $\hat{A}_{i,t} = \frac{r_i - \text{mean}(\mathbf{r})}{\text{std}(\mathbf{r})}$ . The KL penalty, using a fixed reference policy  $\pi_{\text{ref}}$  and coefficient  $\beta$ , encourages stability. The algorithm pipeline is shown in fig. 3.

### 3.3 Reward Design

The reward signal guides the RL agent by evaluating the quality of its generated output sequence. The output sequence  $G_i$  includes structured components for reasoning (`<think>...</think>`) and ranking (`<answer>...</answer>`), as illustrated in fig. 1. The total reward  $r$  is a composite signal designed to encourage both high ranking performance and adherence to the desired output format.

The primary reward signal is based on the rich, order-based information inherent in listwise reranking, measured by Normalized Discounted Cumulative Gain (NDCG). Considering LLM context limits, we use NDCG@10 to evaluate the ranking of top-10 passages. For a generated permutation  $\{p_{\sigma(1)}, p_{\sigma(2)}, \dots, p_{\sigma(n)}\}$  for  $q$ , its score is  $r_{\text{rerank}} = \text{NDCG@10} = \frac{\text{DCG@10}}{\text{IDCG@10}}$ , where  $\text{DCG@10} = \sum_{i=1}^{10} \frac{\text{rel}_i}{\log_2(i+1)}$  and  $\text{IDCG@10} = \sum_{i=1}^{10} \frac{\text{rel}_i^{\text{ideal}}}{\log_2(i+1)}$ . Here, each query has an associated relevance judgments including a set of passages with scores annotated by human expert,  $\text{rel}_i$  is the relevance score

from the annotated relevance judgments for  $p_{\sigma(i)}$  in the generated permutation, and  $\text{rel}_i^{\text{ideal}}$  is the ideal relevance score from the relevance judgments for the passage that would be at rank  $i$  in the ideal ranking for that query. Since the maximum possible NDCG@10 can vary depending on whether the randomly sampled passage set  $P$  contains relevant documents, we define the ranking reward  $r_{\text{rank}}$  as a **relative improvement score**. This approach uses min-max normalization to normalize for the differences in scales of reward scores between two different candidate sets and reduces reward variance (Greensmith et al., 2004; Schulman et al., 2015):

$$r_{\text{rank}} = \frac{r_{\text{rerank}} - r_{\text{init}}}{r^* - r_{\text{init}}}, \quad (5)$$

where  $r^* = \max_{\sigma \in K_n} r(\{p_{\sigma(1)}, p_{\sigma(2)}, \dots, p_{\sigma(n)}\})$  is the best achievable NDCG@10 for that specific passages set  $P$ ;  $r_{\text{init}} = r(\{p_{\tau(1)}, p_{\tau(2)}, \dots, p_{\tau(n)}\})$  is the NDCG@10 of the initial ranking  $\tau$  over  $P$ .

We also incorporate format rewards to encourage the desired output structure. A reward  $r_{\text{format1}} = 1$  is given if both `<think>` and `<answer>` tags are present in the output sequence. A reward  $r_{\text{format2}} = 1$  is given if the content within the `<answer>` tags follows the specified ranking list format (e.g., `[3] > [1] > [2]`).

The final reward  $r$  for a generated sequence is a weighted sum of these components:

$$r = 0.8 \cdot r_{\text{rank}} + 0.1 \cdot r_{\text{format1}} + 0.1 \cdot r_{\text{format2}} \quad (6)$$

### 3.4 Initial State Expansion

Training effective listwise rerankers faces a primary challenge in the scarcity of high-quality training data, defined as query  $q$  paired with relevance judgments. To address this, we introduce a multi-sampling data augmentation method. Utilizing a small dataset of 179 queries from MSMARCO-V2 with fine-grained relevance judgments (0-3), we

randomly sample multiple diverse sets of candidate passages  $P$  for each query  $q$  from its BM25 top 100 retrieval results. The core idea is to evaluate new ranking  $\{p_{\sigma(1)}, \dots, p_{\sigma(n)}\}$  produced from these varied initial ranking  $\tau$  over diverse  $P$  using the same set of relevance judgments. This multi-sampling approach shares conceptual similarities with negative sampling in contrastive learning (Xiong et al., 2020; Zhang et al., 2024a, 2025; BehnamGhader et al., 2024; Lee et al., 2024). By sampling varied initial passage sets and initial ranking, we effectively generate diverse ranking scenarios for a given query, allowing the model to learn robustly from a wider range of non-ideal inputs. This method generates rich listwise ranking data from limited annotations, enabling the model to learn robustly from diverse initial conditions and significantly reducing the need for large-scale, fully annotated query sets.

## 4 Experiments

### 4.1 Experimental Setup

**Training Details** Training data instances are generated by randomly sampling 20 candidate passages per query, repeated 50 times for each of the 179 queries. Samples without any passages marked as relevant (with a score = 0) in the relevance judgments or the initial  $nDCG@10 < 0.1$  are filtered out, resulting in 12k training instances. We choose *Qwen2.5-7B-Instruct* as our baseline model. Training is conducted using the VeRL (Sheng et al., 2024) framework with a batch size of 128 and 32 rollouts per step. We trained the model directly via RL, without an initial SFT phase. The training runs for over 160 steps across 8 H100 GPUs.

**Sliding window reranking** Our REARANK employs a sliding window to get top- $k$  passages as introduced in section 3.1. Following common practice (Sun et al., 2023; Zhuang et al., 2025; Zhang et al., 2024b), we retrieve the top 100 passages using BM25 with plain query ( $n = 100$ ). We set the window size to  $k = 20$ , resulting in 10 LLM calls per query ( $2 \times 100/20 = 10$ ) to get top-10 passages.

**Baselines** To evaluate the effectiveness of REARANK, we compare it against several strong baselines representing different reranking paradigms. Our zero-shot baselines include powerful large language models: Qwen2.5-7B (Yang et al., 2024) and GPT-4 (Achiam et al., 2023). We also incorpo-

rate the state-of-the-art open-source reasoning language model Qwen3-32B (Yang et al., 2025) and Qwen3-235B-A22B, which claim to surpass 671B Deepseek-R1. We adapt these models using the same sliding window strategy and prompt as REARANK, naming them RankQwen and RankGPT, respectively. As a supervised fine-tuning (SFT) baseline, we include RankZephyr (Pradeep et al., 2023b), which is distilled on 105k synthetic ranking data sourced from RankGPT. Furthermore, to compare different RL training strategies, we include Rank-R1 (Zhuang et al., 2024), a concurrent LLM reranker using the same base model (Qwen2.5-7B) but adopting a setwise reranking strategy. This provides valuable insights into the differences between the listwise (used by REARANK) and setwise RL approaches for reranking. The prompts are shown at app. A.

**Benchmarks** To thoroughly evaluate our reasoning-enhanced reranker’s performance and generalization, we select three distinct benchmark suites. We evaluate on the in-domain TREC-DL19 (Craswell et al., 2020a) and DL20 (Craswell et al., 2020b) datasets, both derived from MS-MARCO-V1. For assessing out-of-domain (OOD) generalization, we use BEIR (Thakur et al., 2021), a diverse collection from sources outside of MS-MARCO. Crucially, real-world information retrieval tasks often demand capabilities beyond simple keyword matching or semantic similarity, requiring deeper reasoning to understand complex relationships or logic within the content and the query. To systematically evaluate our reasoning-enhanced REARANK, we utilize the BRIGHT (Su et al., 2024) benchmark, which is specifically designed to test reasoning abilities in retrieval contexts. For all evaluations, we report the  $nDCG@10$  as the evaluation metric.

### 4.2 In-domain & OOD Retrieval Results

As shown in table 1, GPT-4 achieves the best performance across benchmarks, due to its superior text understanding. The Qwen2.5-7B also performs strongly, surpassing the legacy GPT-3.5 on both sets. Our REARANK, based on Qwen2.5-7B trained via our RL approach with reasoning ability, demonstrates performance closely comparable to GPT-4. This suggests the significant potential of advanced reasoning capabilities learned via RL for reranking.

REARANK achieves considerable improvements over the RankQwen2.5-7B baseline: a significant

Model	#Train	In-Domain		Out-of-Domain							
		DL19	DL20	Covid	NFCorpus	DBPedia	SciFact	Signal	News	Robust04	BEIR (Avg)
BM25†	-	50.58	47.96	59.47	30.75	31.80	67.89	33.05	39.52	40.70	43.31
RankQwen <sub>2.5</sub> -7B	zero-shot	68.25	62.73	77.74	37.40	39.83	70.83	31.73	43.24	49.95	50.10
RankGPT <sub>3.5</sub>	zero-shot	65.80	62.91	76.67	35.62	44.47	70.43	32.10	48.85	50.62	51.25
RankGPT <sub>4</sub> ‡	zero-shot	75.59	70.56	85.51	38.47	47.12	74.95	34.40	52.89	57.55	55.84
RankZephyr-7B	105K SFT	73.90	70.60	83.54	38.38	44.34	75.18	31.44	52.35	54.19	54.20
<i>Reasoning Language Model</i>											
RankQwen <sub>3</sub> -32B	zero-shot	73.13	70.00	83.86	36.28	45.44	71.78	32.06	51.73	57.27	54.06
RankQwen <sub>3</sub> -235B	zero-shot	71.94	69.37	83.68	35.64	41.33	63.30	32.53	50.79	58.16	52.20
Rank-R1-7B	72k RL	72.70	68.50	83.12	35.97	43.43	74.47	32.16	48.43	55.17	53.25
REARANK-7B	179 RL	74.16	70.00	81.28	35.20	45.23	75.02	36.00	51.88	57.49	54.59
Δ over baseline*		+5.91	+7.27	+3.54	-2.20	+5.40	+4.19	+4.27	+8.64	+7.54	+4.49

Table 1: **Reranking Agent Results (nDCG@10) on TREC-DL and BEIR Benchmarks.** † denotes initial BM25 retrieval performance. ‡RankGPT<sub>4</sub> reranks top 30 passages from RankGPT<sub>3.5</sub>. All other models rerank on the BM25 top 100 passages. Training data size indicates the number of annotated queries used. \*Baseline is RankQwen<sub>2.5</sub>-7B

6.5% improvement in nDCG@10 on the in-domain benchmarks and a notable 4.5% improvement in nDCG@10 on the OOD benchmark. These substantial gains are particularly impressive given that they are achieved using only 179 annotated queries (used for RL training).

Comparing against SFT RankZephyr-7B, REARANK-7B demonstrates comparable performance on TREC-DL while achieving superior results in BEIR. This finding suggests that while SFT can be effective for in-domain data, our RL approach may offer enhanced robustness and better generalization capabilities when applied to out-of-domain tasks.

Evaluating against powerful reasoning language models, including the large Qwen3 and the concurrent Setwise Rank-R1, reveals significant strengths of REARANK. Despite being trained on a dataset of only 179 queries (0.2% of Rank-R1’s reported data), REARANK-7B surpasses Setwise Rank-R1 across benchmarks. Furthermore, REARANK-7B’s performance exceeds both Qwen3-32B and Qwen3-235B. REARANK-7B achieves superior reranking performance with less training data and a more compact size than state-of-the-art methods. Interestingly, Qwen3-32B surpasses Qwen3-235B. Our investigation, consistent with (Marjanović et al., 2025), suggests Qwen3-235B’s excessive self-reflection (marked by "wait") leads to confusion and degraded performance.

### 4.3 Reasoning-intensive Retrieval Results

Table 2 presents performance results on the reasoning-intensive BRIGHT benchmark. Notably, REARANK-7B even outperforms the powerful GPT-4 model on this benchmark, highlighting its strong reasoning capabilities developed through RL training. The SFT method, RankZephyr-7B, performs

considerably poorer on BRIGHT, falling below the lexical-based BM25 baseline. This reinforces our observation that SFT generalizes poorly to out-of-domain and reasoning-intensive scenarios.

Comparing with the concurrent Setwise Rank-R1, our listwise REARANK-7B achieves better performance on the BRIGHT benchmark also. This superior performance, particularly against another RL-trained model, underscores the effectiveness of our approach. Furthermore, while REARANK-7B is smaller and does not undergo general reasoning training (e.g. *math, coding, agent*) like Qwen3, its performance remains closely comparable. This near parity, despite inherent disadvantages, further confirms our method’s effectiveness.

These strong results on a reasoning-intensive task against competitive LLM baselines (GPT-4, Rank-R1) highlight the efficacy of REARANK’s design. Its RL framework, trained on a limited high-quality dataset via our synthesis pipeline, enables learning complex reranking strategies. The listwise nature provides a richer signal for robust ranking compared to setwise methods, while also offering inference efficiency (fewer LLM calls).

### 4.4 Ablation Studies

To quantify the effectiveness of individual components within REARANK, we conducted ablation studies, summarized in table 3. Our first investigation examined the effect of applying the REARANK’s reasoning prompt directly to Qwen2.5-7B. While Qwen2.5-7B shows marginal improvement with the reasoning prompt over its zero-shot baseline, it significantly underperforms REARANK. This suggests that prompting alone is insufficient for eliciting robust reasoning in this context.

We then investigate the impact of data filtering.

Model	#Train	StackExchange							Coding		Theorem-based			Avg.
		Bio.	Earth.	Econ.	Psy.	Rob.	Stack.	Sus.	Pony	LC.	AoPS	TheoT.	TheoQ.	
BM25†	-	18.2	27.9	16.4	13.4	10.9	16.3	16.1	4.3	24.7	6.5	2.1	7.3	13.7
RankQwen <sub>2.5</sub> -7B	zero-shot	22.7	25.8	14.6	18.7	14.2	11.7	21.4	5.3	23.9	6.0	7.4	7.9	15.0
RankGPT <sub>4</sub>	zero-shot	33.8	34.2	16.7	27.0	22.3	27.7	11.1	15.6	3.4	1.2	8.6	0.2	16.8
RankZephyr-7B	105K SFT	21.9	23.7	14.4	10.3	7.6	13.7	16.6	6.5	24.7	6.8	2.0	7.3	13.0
<i>Reasoning Language Model</i>														
RankQwen <sub>3</sub> -32B	zero-shot	24.9	29.4	20.9	25.7	18.3	16.0	23.2	7.6	27.6	7.8	8.9	8.4	18.2
RankQwen <sub>3</sub> -235B	zero-shot	26.4	26.7	22.1	26.3	18.8	17.0	24.9	8.2	27.2	7.7	11.7	8.6	18.8
Rank-R1-7B	72k RL	26.0	28.5	17.2	24.2	19.1	10.4	24.2	4.3	19.8	4.3	10.9	8.3	16.4
REARANK-7B	179 RL	23.4	27.4	18.5	24.2	17.4	16.3	25.1	8.0	27.0	7.4	9.5	7.9	17.7
$\Delta$ over baseline*		+0.8	+1.7	+4.0	+5.5	+3.3	+4.6	+3.7	+2.7	+3.0	+1.4	+2.1	0.0	+2.7

Table 2: **Reranking Agent Results (nDCG@10) on BRIGHT**. † represent initial retrieval; all other models show reranking performance on the top 100 BM25 results. \*Baseline is RankQwen<sub>2.5</sub>-7B

Model Variant	TREC-DL	BEIR	BRIGHT
Qwen2.5-7B (baseline)	65.5	50.1	15.0
+Reasoning Prompt	65.9	51.4	15.4
wo/ Filter nDCG@10 < 0.1	71.3	53.6	16.9
w/ $r_{\text{rank}} = S_{\text{rerank}}$	70.9	53.2	16.7
w/ $r_{\text{rank}} = S_{\text{rerank}} - S_{\text{init}}$	71.5	54.0	17.2
w/ direct SFT	66.7	50.7	14.7
REARANK-7B (full model)	72.0	54.6	17.7

Table 3: **Ablation of components of the approach.**

The "wo/ Filter nDCG@10 < 0.1" variant removes the filter on low-quality candidate sets (best possible nDCG@10 < 0.1)—many lacking relevant passages and yielding zero reward—which degrades performance. This underscores the importance of curating high-quality training instances.

Next, we explored reward function design. Using raw NDCG@10 ("w/  $r_{\text{rank}} = S_{\text{rerank}}$ ") results in lower performance due to high variance. Subtracting the initial score ("w/  $r_{\text{rank}} = S_{\text{rerank}} - S_{\text{init}}$ ") improved stability but still underperforms REARANK. This could be due to small learning signals as a result of small reward value scale. Our full model’s normalized reward function provided more effective guidance, yielding the best results.

Finally, to isolate the benefits of our RL training approach from those gained solely from training on high-quality data, we also trained a SFT baseline ("w/ direct SFT"). This model was trained on 12k instances representing the best possible rankings derived from our multi-sampled candidate sets based on relevance judgments. Trained on this small dataset, the SFT baseline showed marginal improvements on in-domain and OOD tasks compared to the base Qwen2.5-7B model, but importantly, it negatively impacted the model’s reasoning ability on the BRIGHT benchmark. This underscores the necessity of the RL approach for effectively leveraging small, high-quality data to train a

robust and reasoning-capable reranking agent.

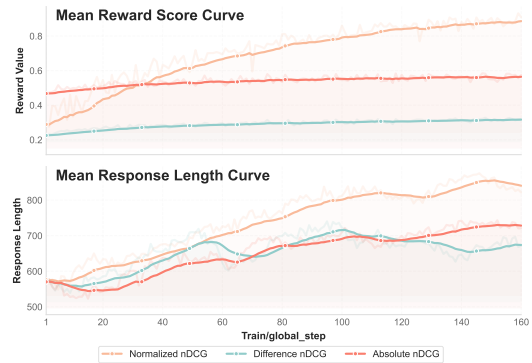


Figure 4: (Top) Reward evolving curve (Bottom) Response length curve.

## 5 Analysis

**Analysis of Reward Functions** We investigate the impact of different reward functions on REARANK’s training. We compare three nDCG@10 formulations: **Normalized nDCG** (our method: scaled by ideal nDCG), **Absolute nDCG** ( $S_{\text{rerank}}$ ), and **Difference nDCG** ( $r_{\text{rank}} = S_{\text{rerank}} - S_{\text{init}}$ , improvement over initial).

The top panel of Figure 4 shows reward curves. Normalized nDCG consistently grows, reaching  $\sim 0.8$  by 100 steps, signifying that the achieved ranking quality is approximately 80% of the ideal quality for the candidate set. Absolute nDCG saturates early ( $\sim 50$  steps). Difference nDCG shows limited progress, plateauing at  $\sim 0.15$  average improvement. This suggests Normalized nDCG provides a more effective signal for learning towards optimal ranking quality. The bottom panel shows response length trends. Normalized nDCG yields generally longer responses ( $\sim 850$  tokens). Other functions saturate earlier ( $\sim 700$  tokens), suggesting that the stronger signal from Normalized nDCG encourages more detailed responses and reasoning.

### Query

Claim in article about why insects are attracted to light In this article they are addressing the reason insects are attracted to light when they say Heat radiation as an attractive component is refuted by the effect of LED lighting, which supplies negligible infrared radiation yet still entraps vast numbers of insects. I don't see why attraction to LEDs shows they're not seeking heat. Could they for example be evolutionarily programmed to associate light with heat? So that even though they don't encounter heat near/on the LEDs they still "expect" to?

### Before RL

<think>  
 1. [1] - This passage is about insect population declines and doesn't address why insects are attracted to light or the reasoning mentioned in the query.  
 2. [2] - This passage is about the history of electromagnetic radiation and doesn't address the attraction of insects to light.  
 3. [3] - This passage is about the history of electromagnetic radiation and doesn't address the attraction of insects to light.  
 4. [4] - This passage is about the properties of translucent objects and doesn't address the attraction of insects to light.  
 5. [5] - This passage is about insect sensory abilities and doesn't address the attraction of insects to light.</think>

### After RL

<think>  
 - Passage [1]: Mentions color perception in animals but does not discuss insect attraction to light or heat radiation. Relevant keywords: color perception, red, bulls.  
 - Passage [2]: Same as passage [1]. Relevant keywords: color perception, red, bulls.  
 - Passage [3]: Discusses the function of ocelli in insects but does not address light attraction or heat radiation. Relevant keywords: ocelli, insects, flight, image focusing.  
 - Passage [4]: Same as passage [3]. Relevant keywords: ocelli, insects, flight, image focusing.  
 - Passage [5]: Discusses the perception of darkness and the physics of light absorption but does not address insect attraction to light or heat radiation. Relevant keywords: perception of darkness, light absorption, physics.</think>

Figure 5: Reasoning patterns: Before- vs. After-RL training under identical prompt and query.

Model	Reasoning	TREC-DL	BEIR	BRIGHT
Qwen3-32B	✓	71.6	54.1	18.2
Qwen3-32B	✗	70.9	54.3	17.8
Δ		+0.6	-0.2	+0.4
REARANK-7B	✓	72.0	54.6	17.7
REARANK-7B	✗	68.2	52.9	16.4
Δ		+3.9	+1.7	+1.3
Qwen2.5-7B	-	65.5	50.1	15.0

Table 4: Performance with Reasoning activated and deactivated. Δ is improvement with reasoning.

**Is reasoning helpful?** The reasoning ability of REARANK is activated by the system prompt used in RL training (see app.A). While Qwen3-32B also provides a switch to enable or disable the "thinking" mode, our observations, detailed in table 4, indicate that enabling reasoning yields only marginal improvements in its reranking performance. Specifically, Qwen3-32B shows slight gains on TREC-DL and BRIGHT (+0.6 and +0.4, respectively) and a minor decrease on BEIR (-0.2), suggesting *its high performance stems primarily from strong pre-training, rather than reasoning capacity*.

In contrast, reasoning is core to our specialized reranking agent, REARANK, and significantly enhances its performance. As the table illustrates, REARANK-7B without reasoning (use zero-shot prompt), already outperforms the Qwen2.5-7B baseline, demonstrating an inherent improvement in reranking capacity. However, incorporating reasoning leads to considerable gains, underscoring the importance of reasoning learned via RL.

**Reasoning Pattern** As illustrated in fig. 5, RL training profoundly impacts reasoning patterns. The trained model learns a strategic reranking approach, reasoning about the relevance of the passage to the query and extracting key judgment

words. It also intelligently leverages terms like "same" for concise comparisons with prior passages, reducing verbose reasoning while still providing keywords. The model without RL training, even with a reasoning prompt, does not show such strategy and employs shorter reasoning chains.

**Is improved reasoning transferable?** To investigate the transferability of improved reasoning gained from our reasoning-based reranking RL training, we evaluate the model on mathematical reasoning questions. Following (Ye et al., 2025), we report the pass@1 score averaged over 16 samples with a temperature of 0.7 on the AIME 2024 and AMC datasets. As shown in Table 5, we observe consistent improvements on both the challenging math tasks. This improvement suggests that training on the reranking task can, to a certain extent, transfer to other reasoning tasks.

Model	AIME 2024	AMC
Qwen2.5-7B-Instruct	11.87	51.41
(Ours) Rearank-7B	12.92	52.66

Table 5: Math Reasoning Transfer Results (Pass@1)

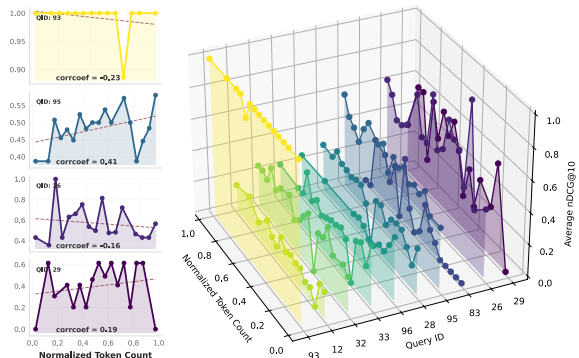


Figure 6: Impact of reasoning length. Data points are binned into 20 equal-width intervals by token count.



## Impact of Reasoning Length on Performance

We analyzed the impact of reasoning length on REARANK’s reranking performance by repeatedly reranking biology samples from BRIGHT (50 times per query, temp. = 0.6), filtering instances with 0 scores. Contrary to (Marjanović et al., 2025), Figure 6 reveals no clear correlation between reasoning length and reranking performance.

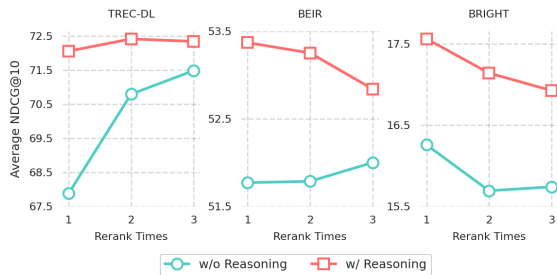


Figure 7: Multiple reranking results of REARANK.

**Multiple Rerank Pass Needed** Analyzing the impact of multiple reranking passes with REARANK (evaluating performance with and without reasoning) reveals mixed results across benchmarks (fig. 7). Multiple passes improve performance on TREC-DL and BEIR without reasoning, but degrade it on BRIGHT. With reasoning, gains are seen on TREC-DL, but performance is harmed on other benchmarks. These findings indicate that for REARANK, a single reranking pass is sufficient.

## 6 Conclusion

We presented REARANK, a pioneering reasoning listwise reranking agent trained via Reinforcement Learning. REARANK significantly outperforms baselines and achieves competitive, even superior, results compared to GPT-4 and Qwen3 models across various benchmarks, notably with only 179 labeled training samples. Our analysis confirms that the RL-acquired reasoning capabilities transfer, facilitating new and effective reranking strategies.

## Limitations

While REARANK demonstrates promising results, several limitations should be acknowledged. Firstly, the quality and faithfulness of its generated explanations for ranking decisions, which may contain a certain degree of hallucination, have not been formally evaluated. Secondly, its performance heavily relies on the quality of initial candidates provided by BM25, which potentially limits improvements in scenarios with poor initial retrieval.

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## A Prompt Template

We provide the prompt template used in the experiments. Each prompt is concatenation of system prompt and user instruction. The user iteratively provides each passage paired with its original rank identifier. The prompt concludes with a post prompt message containing the ranking query and explicit output format requirements.

### A.1 Reasoning prompt

This is the prompt used by REARANK.

#### Reasoning System Prompt

You are DeepRerank, an intelligent assistant that can rank passages based on their relevancy to the search query. You first thinks about the reasoning process in the mind and then provides the user with the answer. I will provide you with passages, each indicated by number identifier []. Rank the passages based on their relevance to the search query. Search Query: [QUERY]. Rank the [NUM] passages above based on their relevance to the search query. The passages should be listed in descending order using identifiers. The most relevant passages should be listed first. The output format should be <answer> [] > [] </answer>, e.g., <answer> [1] > [2] </answer>.

#### Reasoning User Instruction

**Iterative User Message (per passage):** [RANK] [Passage Content (truncated)]

**Iterative Assistant Message (per passage):** Received passage [RANK].

**Post Prompt:** Please rank these passages according to their relevance to the search query: "[QUERY]" Follow these steps exactly:

1. First, within <think> tags, analyze EACH passage individually:
  - Evaluate how well it addresses the query
  - Note specific relevant information
2. Then, within <answer> tags, provide ONLY the final ranking in descending order of relevance using the format: [X] > [Y] > [Z]

### A.2 Zero-shot prompt

This is original prompt used for RankQwen and RankGPT.

#### Zero-shot System Prompt

You are RankGPT, an intelligent assistant that can rank passages based on their relevancy to the query. I will provide you with [NUM] passages, each indicated by number identifier []. Rank the passages based on their relevance to query: [QUERY].

#### Zero-shot User Instruction


**Iterative User Message (per passage):** [RANK] [Passage Content (truncated)]

**Iterative Assistant Message (per passage):** Received passage [RANK].

**Post Prompt:** Search Query: [QUERY]. Rank the [NUM] passages above based on their relevance to the search query. The passages should be listed in descending order using identifiers. The most relevant passages should be listed first. The output format should be [] > [], e.g., [1] > [2]. Only response the ranking results, do not say any word or explain.

## B Case Study


Figure 8 provides an illustrative example from the BRIGHT dataset, detailing the inference reasoning process employed by REARANK. For each passage, the agent first analyzes its content to understand its key themes and then determines its relationship to the query. Relevant information, typically keywords, is then extracted based on this analysis. We conducted a manual evaluation of the generated reasoning content and found it to be of high quality, contributing to the trustworthiness of the system's outputs. This reasoning process ultimately informs the final ranking of passages presented in the answer.

**Query:** Is there an RGB equivalent for smells? Millions of colors in the visible spectrum can be generated by mixing red, green and blue - the RGB color system. Is there a basic set of smells that, when mixed, can yield all, or nearly all detectable smells? 

**Passage 1:** viewing distance, the separate sources are indistinguishable, which the eye interprets as a given solid color. All the pixels together arranged in the rectangular screen surface conforms the color image. During digital image processing each pixel can be represented in the computer memory or interface hardware (for example, a graphics card) as binary values for the red, green, and blue color components. When properly managed, these values are converted into intensities or voltages via gamma correction to correct the inherent nonlinearity of some devices, such that the intended intensities are reproduced on the display

**Passage 2:** Effects[edit] A color blind person will have decreased (or no) color discrimination along the red–green axis, blue–yellow axis, or both. However, the vast majority of the color blind are only affected on their red–green axis. The first indication of color blindness generally consists of a person using the wrong color for an object, such as when painting, or calling a color by the wrong name. The colors that are confused are very consistent among people with the same type of color blindness. Normal sight Deuteranopic sight Protan

**Passage 3:** more or less saturated depending on the difference of the strongest and weakest of the intensities of the primary colors employed. When one of the components has the strongest intensity, the color is a hue near this primary color (red-ish, green-ish, or blue-ish), and when two components have the same strongest intensity, then the color is a hue of a secondary color (a shade of cyan, magenta or yellow). A secondary color is formed by the sum of two primary colors of equal intensity: cyan is green+blue, magenta is blue+red, and yellow

**<think>** 

- Passage [1]: This passage discusses the RGB color system and how pixels are represented in digital images. It mentions the RGB color compon, which is relevant to the query about the RGB equivalent for smells. Specific relevant information: RGB color system, pixel representation.
- Passage [2]: This passage discusses color blindness and the effects it has on color discrimination. It does not directly address the query about a RGB equivalent for smells. Specific relevant information: color blindness, red-green axis, blue-yellow axis.
- Passage [3]: This passage explains how the RGB color system works and how colors are mixed. It mentions the RGB color compon, which is relevant to the query about the RGB equivalent for smells. Specific relevant information: RGB color system, color mixing, primary colors

**</think>**


**<answer> [3] > [1] > [2] </answer>** 

Figure 8: Examples from biology split of BRIGHT, only 3 passages selected for better visibility. Relevant sentences in the passages and Key reasoning content in the thinking process are highlight.