Unveiling Selection Biases: Exploring Order and Token Sensitivity in Large Language Models

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Abstract

In this paper, we investigate the phenomena of "selection biases" in Large Language Models (LLMs), focusing on problems where models are tasked with choosing the optimal option from an ordered sequence. We delve into biases related to option order and token usage, which significantly impact LLMs' decision-making processes. We also quantify the impact of these biases through an extensive empirical analysis across multiple models and tasks. Furthermore, we propose mitigation strategies to enhance model performance. Our key contributions are threefold: 1) Precisely quantifying the influence of option order and token on LLMs, 2) Developing strategies to mitigate the impact of token and order sensitivity to enhance robustness, and 3) Offering a detailed analysis of sensitivity across models and tasks, which informs the creation of more stable and reliable LLM applications for selection problems.

1 Introduction

Large Language Models (LLMs) have demonstrated remarkable abilities across various tasks (OpenAI, 2023; Gemini Team, 2023; Touvron et al., 2023), leading to their widespread adoption in downstream applications. In particular, the utilization of zero-shot or few-shot prompting techniques emerged as a highly convenient approach in harnessing the potential of LLMs, since these techniques empower end-users to solve a wide range of tasks without the need for extensive fine-tuning.

Despite LLMs' impressive performance and convenience, empirical investigations have found that their output is highly sensitive to the choice of prompts, and even subtle modifications of instructions or demonstrations have considerable influence on their performance. To address this issue, several works have been dedicated to the identification and mitigation the inherent biases in LLMs, aiming to enhance their robustness and reliability (Zhao et al., 2021; Si et al., 2023; Fei et al., 2023).

In this study, our focus is directed towards the domain of "selection problem", where LLMs are instructed to select the optimal choice from an ordered sequence of choices. This problem encompasses a variety of downstream applications, including but not limited to classification, multiple-choice questions (Zheng et al., 2024; Pezeshkpour and Hruschka, 2023), and model evaluation scenarios (Zheng et al., 2023; Wang et al., 2023; Shen et al., 2023). In our analysis, we identifies specific biases within the context of selection problems, which we call "selection biases" to encapsulate these discernible tendencies. These biases manifest as systematic deviations in LLMs' preferences, and a thorough understanding of these biases is pivotal for enhancing the robustness of LLMs across the spectrum of applications under the scope of selection problems. Our subsequent exploration delves into the characterization, quantification, and mitigation strategies to address these biases. It is crucial to highlight that our analysis centers on the zero-shot setting. This choice distinguishes our work from previous endeavors, which predominantly concentrate on few-shot settings, making it difficult to disentangle biases stemming from in-context demonstrations.

Our contributions can be summarized as follows: **1)** We quantify the influence of option order and token on the decision-making processes of various LLMs when tackling selection problems, providing clear insights into how these factors affect model performance; **2)** We introduce strategies to mitigate the effects of token and order sensitivity, leading to performance improvements across a broad spectrum of tasks; **3)** We offer a thorough understanding of the sensitivity landscape through an empirical study encompassing different models, tasks, and sensitivity settings. The analysis enables us to identify the most effective strategies for addressing sensitivity issues in diverse task scenarios.

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2 Related Work

Biases of LLMs. Several studies have delved into the biases of LLMs. Zhao et al. (2021) identifies three notable biases: majority label bias, where LLMs exhibit a propensity to output the most frequent label in few-shot demonstrations; recency bias, which is the tendency to repeat the label appearing towards the end of the prompt; and common token bias, manifesting as the inclination to output tokens prevalent in the pre-training distribution. Fei et al. (2023) further identifies the domain-label bias, which could be detected and estimated using random in-domain words from the task corpus. Additionally, Si et al. (2023) focuses on feature bias, which is the tendency to use one feature over another to predict the label, even when both features in the prompt are equally effective for predicting the label. However, these works mainly focus on the few-shot settings, which fails to disentangle the effects of selection biases from biases caused by in-context examples.

Selection Problem of LLMs. Previous studies have explored the use of LLMs in tackling selection problems. In Multiple Choice Questions (MCQs), Robinson and Wingate (2023) demonstrated the application of LLMs to MCQs, focusing on how different prompting techniques influence the model's decision-making process. Pezeshkpour and Hruschka (2023) highlighted how LLMs are affected by position bias when addressing MCQs, while Zheng et al. (2024) pinpointed token bias as the primary reason LLMs are not robust selectors in this context. In evaluation scenarios, Shen et al. (2023) employed LLMs to assess the abstractive summarization outcomes of models, introducing three distinct settings: reason-then-score (RTS), MCQ scores, and head-to-head comparison (H2H). Zheng et al. (2023) applied LLMs as evaluators in chatbot interactions, employing a two-round approach rather than a single-step evaluation. Wang et al. (2023) discovered that LLMs' evaluation fairness is significantly compromised by option position bias, indicating that LLMs can be heavily influenced by the positioning of options.

3 Experimental Setup

3.1 Evaluation Tasks

We experiment on six multi-choice tasks with the number of choice options varying from two to five. The six benchmarks are: ARC-Challenge (Clark et al., 2018), HellaSwag (Zellers et al., 2019), MMLU (Hendrycks et al., 2021), Winogrande (Sakaguchi et al., 2019), MathQA (Amini et al., 2019), and OpenBookQA (Mihaylov et al., 2018).

We select these datasets due to their coverage of a wide range of domains, including commonsense reasoning, STEM, social sciences, humanities, etc. This diversity ensures a comprehensive evaluation across various fields of knowledge. Data statistics details are shown in Table 5 in Appendix A due to space constrains.

3.2 Models

We adopt six instruction-tuned LLMs in our experiment, encompassing both commercial APIs and open-source models. From the commercial side, our selection included PaLM 2 (Anil et al., 2023), Gemini Pro (`gemini-pro`) (Gemini Team, 2023), and ChatGPT (`gpt-3.5-turbo-1106`) (OpenAI, 2022). For open-source models, we employ LLaMA 2 (Touvron et al., 2023) with different model sizes (`Llama-2-chat-7b/13b/70b`).

3.3 Notaions

For a given question q, the number of options available is denoted by k. Each option within this range, from position 1 to k, is characterized by an option symbol s_i and the corresponding option content c_i, where $s_i \in S_q$ and $c_i \in C_q$. Here, S_q denotes the option symbol set, and C_q represents the option content set. For instance, consider a question q that offers four possible answers with the symbol set $S_q = \{s_1, s_2, s_3, s_4\}$ and $C_q = \{c_1, c_2, c_3, c_4\}$; in this scenario, the representation of q can be expressed as $q = \{(s_1, c_1), (s_2, c_2), (s_3, c_3), (s_4, c_4)\}$.

3.4 Other Details

Following HuggingFace Open LLM Leaderboard (Beeching et al., 2023), we utilize the EleutherAI lm-harness (Gao et al., 2023) tool to manage datasets for our experiments. For commercial APIs, we set the temperature to 0 to guarantee reproducibility. For open-source models, we employ Azure AI Studio to deploy various sizes of `Llama-2-Chat` for parallel processing, optimizing our experimental setup for efficiency and scalability. Additionally, all experiments in this study are conducted in the zero-shot setting, with the prompts being consistent with those used in prior research (Zheng et al., 2023; Wang et al., 2023). Details of the prompts can be found in Appendix B.

Model/	ARC	HellaSwag	MMLU	Winogrande	MathQA	OpenBookQA
Setting	Acc / Fluct.	Acc / Fluct.	Acc / Fluct.	Acc / Fluct.	Acc / Fluct.	Acc / Fluct.
PaLM 2/T	82.15 / 4.98	91.06 / 4.82	64.32 / 15.94	67.48 / 23.92	30.87 / 36.23	84.7 / 4.2
PaLM 2/O	81.29 / 14.42	90.85 / 10.19	63.70 / 25.59	72.93 / 10.34	30.18 / 67.59	85.40 / 9.00
PaLM 2/B	82.32 / 14.60	92.12 / 7.47	63.46 / 32.08	68.07 / 34.58	30.55 / 58.68	86.40 / 9.24
Gemini Pro/T	85.15 / 5.67	79.09 / 15.97	65.75 / 18.99	61.29 / 15.07	26.38 / 34.71	83.10 / 8.20
Gemini Pro/O	84.51 / 15.71	79.04 / 22.55	64.80 / 32.10	60.46 / 45.62	26.31 / 66.50	82.0 / 19.80
Gemini Pro/B	84.42 / 15.71	78.77 / 23.46	64.38 / 36.29	60.46 / 61.56	26.65 / 71.56	83.40 / 19.00
GPT 3.5/T	75.24 / 15.87	78.74 / 14.54	58.29 / 24.20	54.46 / 22.08	14.07 / 28.19	71.90 / 15.20
GPT 3.5/O	75.79 / 19.62	78.76 / 18.73	58.36 / 31.01	54.97 / 29.83	14.20 / 30.94	70.60 / 26.40
GPT 3.5/B	77.98 / 17.94	78.69 / 19.57	59.36 / 28.76	54.50 / 40.51	12.83 / 62.15	73.70 / 22.29
LLaMA2-7B/T	38.07 / 53.20	39.21 / 57.2	32.22 / 51.51	46.65 / 4.27	15.31 / 61.35	29.60 / 62.45
LLaMA2-7B/O	37.38 / 71.43	39.30 / 63.03	30.38 / 66.41	47.00 / 96.57	16.18 / 56.80	32.90 / 82.73
LLaMA2-7B/B	39.31 / 68.13	41.17 / 60.54	31.42 / 74.53	46.72 / 100.00	16.89 / 70.98	33.70 / 75.40
LLaMA2-13B/T	45.62 / 38.64	38.02 / 36.62	36.96 / 38.90	44.00 / 88.67	18.91 / 48.01	37.70 / 48.04
LLaMA2-13B/O	45.97 / 36.29	38.11 / 54.46	36.67 / 39.18	43.80 / 3.84	18.53 / 47.08	39.40 / 37.14
LLaMA2-13B/B	46.18 / 45.55	37.32 / 52.44	36.78 / 54.73	45.42 / 99.56	19.77 / 76.17	41.90 / 48.43
LLaMA2-70B/T	60.17 / 37.40	58.66 / 52.94	44.95 / 55.06	47.71 / 96.30	23.13 / 73.70	58.00 / 50.30
LLaMA2-70B/O	60.17 / 35.88	58.85 / 50.80	46.29 / 49.62	48.62 / 20.08	23.25 / 82.04	55.10 / 44.78
LLaMA2-70B/B	61.37 / 35.16	64.42 / 27.77	47.32 / 42.57	47.59 / 100.00	24.54 / 37.82	60.40 / 38.60

Table 1: Results of model sensitivity experiment across models and tasks, with sensitivity settings denoted as **T** (Token), **O** (Order), and **B** (Both). **Acc** (%) represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting. For each model, the minimum fluctuation rate is highlighted in blue, signifying lower sensitivity and the maximum rate is marked in red, indicating higher sensitivity.

4 Investigation on LLM Sensitivity

While prior research has touched upon biases in LLMs concerning MCQs, with notable findings on position bias and token bias, our work stands out by delving deeper into unexplored territories of the combined impact of option order and token usage within MCQs. We uncover novel insights into the decision-making processes of LLMs that have yet to be extensively explored in the existing literature.

4.1 Setups

We adhere to the notations established in Section 3.3, allowing for a more coherent and precise description of the experimental setups.

Token Sensitivity. To assess the impact of token sensitivity, we employ the default option symbol set $S_q = \{A, B, \dots, S_{qk}\}$ for each question q, where k represents the number of option contents for question q and and S_{qk} represents the k-th letter of the alphabet from A to Z. For each question, we conduct experiments with two distinct requests to the LLM. The first request is defined as follows:

$$r_{forward} = \{(s_i, c_i) \mid i = 1, 2, \dots, k\} \quad (1)$$

Here, s_i refers to the i-th option symbol in S_q, and c_i represents the i-th option content of C_q, indicating the i-th answer candidate for the question.

Conversely, the second request, $r_{backward}$, introduces a reversed arrangement of the option symbols, as detailed below:

$$r_{backward} = \{(s_{k-i+1}, c_i) \mid i = 1, 2, \dots, k\} \quad (2)$$

Subsequently, the results of $r_{forward}$ and $r_{backward}$ are analyzed.

Order Sensitivity. To determine the influence of order sensitivity, we adopt a strategy of coupling each option symbol with its corresponding option content, thereby aiming to nullify the effects of token sensitivity. Consistent with the settings described previously, the option symbol set S_q is $\{A, B, \dots, S_{qk}\}$. $r_{forward}$ and $r_{backward}$ are:

$$r_{forward} = \{(s_i, c_i) \mid i = 1, 2, \dots, k\} \quad (3)$$

$$r_{backward} = \{(s_i, c_i) \mid i = k, k-1, \dots, 1\} \quad (4)$$

Both Sensitivity. In practical scenarios, a common remediation strategy involves rearranging the order of option content. This maneuver inherently addresses both order and token sensitivities. It is anticipated that if the biases induced by these sensitivities align, their cumulative effect on sensitivity will be magnified. Conversely, if they are in opposition, their effects will likely be mitigated. Following the previously described setting, where the symbol set S_q is $\{A, B, \dots, S_{qk}\}$, we define $r_{forward}$ and $r_{backward}$ as follows:

$$r_{forward} = \{(s_i, c_i) \mid i = 1, 2, \dots, k\} \quad (5)$$

$$r_{backward} = \{(s_i, c_{k-i+1}) \mid i = 1, 2, \dots, k\} \quad (6)$$

4.2 Measurement of Sensitivity

To assess the model's sensitivity, we introduce the *Fluctuation Rate* (FR), a metric designed to quantify the variability in responses between $r_{forward}$ and $r_{backward}$. The equation for FR is given by:

$$FR = \frac{\sum_{i=1}^{N}(r_{forward}(i) \neq r_{backward}(i))}{N} \quad (7)$$

where $\sum_{i=1}^{N}(r_{forward}(i) \neq r_{backward}(i))$ denotes the number of instances where the outcomes of $r_{forward}$ and $r_{backward}$ are not identical, and N represents the sample size of that task. Thus, FR reflects the fraction of all questions where the two requests yield divergent results.

4.3 Overall Observation

Table 1 comprehensively summarizes our sensitivity experiments across various LLMs. We also provide detailed breakdowns of the MMLU's performance across its 57 subtasks in Appendix C. In powerful LLMs, PaLM 2, Gemini Pro, and GPT-3.5, we observe a notable trend: they are more sensitive to option order than to symbols/tokens in 17 out of 18 cases. An exception to this trend is observed with the Winogrande dataset, where PaLM 2 shows increased sensitivity to token variations. In *both sensitivity* setting, which examines the joint effects of token and order sensitivities, we find that in 11 out of 18 cases, the combined influence is the most pronounced. This indicates that in more than half of the cases, the directional impacts of token and order sensitivities tend to align.

Conversely, the open-source LLM, LLaMA 2 (`Llama-2-chat`), across its varying sizes, does not exhibit a consistent sensitivity trend towards token and order. For instance, while the 7B model appears more sensitive to order, the 13B and 70B models do not follow this pattern. Although Table 1 indicates that the 13B and 70B models are more sensitive to token differences in 9 out of 12 instances, the discrepancy in the fluctuation rate between token and order sensitivity is marginal.

4.4 Relation between Difficulty and Sensitivity

Table 1 reveals an interesting pattern: tasks with higher accuracy levels, such as ARC Challenge, HellaSwag, and OpenBookQA, tend to exhibit lower fluctuation rates. This observation prompts us to question whether there is a relationship between the difficulty of a task and the sensitivity of a model to it. To further investigate this hypothesis, we analyze the sensitivity across 57 MMLU subtasks. For detailed results per model, we refer to Appendix C, as mentioned in Section 4.3, due to space constraints.

Figure 1 illustrates the correlation between task accuracy and fluctuation rates across six models, encompassing three advanced commercial LLMs and three open-source models of varying sizes. This comparison offers a unique opportunity to assess the impact of scaling model parameters. For comprehensive insight, we integrate the previously discussed settings—*token sensitivity*, *order sensitivity*, and *both sensitivity*—into a single diagram per model, facilitating a clear understanding of how task difficulty correlates with model sensitivity.

Results from PaLM 2, Gemini Pro, GPT-3.5, and LLaMA 2 70B appear to support our hypothesis: more challenging tasks, characterized by lower accuracy, tend to exhibit greater sensitivity, as indicated by higher fluctuation rates. This aligns with our intuition that models are more confident and thus less sensitive to fluctuations in easier questions. A notable observation pertains to the smaller LLaMA 2 models, specifically the 7B and 13B versions. Tasks that are more straightforward for other powerful LLMs pose significant challenges to these models, leading to lower accuracy and a muted trend in sensitivity as tasks vary in difficulty. However, a closer analysis of the 7B, 13B, and 70B models reveals a gradual manifestation of the expected trend. The shift from the 7B to the 13B model, for instance, corresponds with our expectation in the *both sensitivity* setting. With further increases in model size, the 70B model exhibits the predicted correlation between task difficulty and model sensitivity across all examined settings.

	A (%)	B (%)	C (%)	D (%)
Ground truth	22.58	26.52	**26.52**	24.38
PaLM 2	18.30	26.29	**28.69**	26.72
Gemini Pro	18.03	27.81	**29.10**	25.06
GPT 3.5	18.46	29.48	**30.18**	21.87
LLaMA2-7B	**57.39**	19.98	22.62	0.00
LLaMA2-13B	1.41	42.03	**43.44**	13.13
LLaMA2-70B	7.23	31.78	**41.67**	19.32

Table 2: Option proportion statistics and ground truth label proportions for the ARC dataset. The most frequent option in each row is highlighted in **bold**.

4.5 LLMs' Option Tendency

To understand LLMs' behavior, we calculated the option proportion statistics to analyze their tendencies. Specifically, we calculated the answer distri-

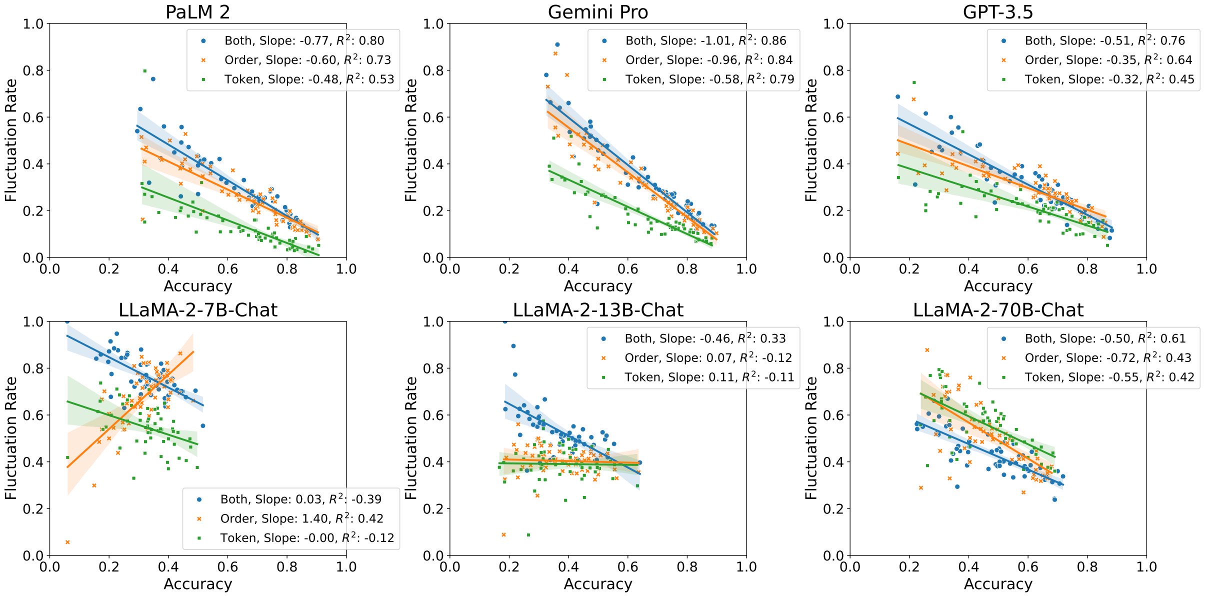

Figure 1: Correlation between model accuracy and fluctuation rates under different sensitivity settings: *Token*, *Order*, and *Both*. Including linear regression lines for each setting, alongside slope and R^2 values, to clearly show the relation between model performance and fluctuation rates.

bution of $r_{forward}$ and detailed the information for each option alongside the ground truth label proportion. Table 2 shows the results for the ARC dataset, highlighting the similarities and differences in selection biases among various LLMs. According to the results, most models, except for LLaMA2-7B, exhibit a notable bias towards option C compared to the ground truth proportion. Due to space limitations, statistics for the other five datasets, including HellaSwag, MMLU, Winogrande, MathQA, and OpenBookQA, are included in Appendix D. Generally, most models, except for LLaMA2-7B, show a bias towards options B or C.

5 Methodology

To mitigate the impact of sensitivity to tokens and/or order and improve model stability, we propose three methods tailored to different contexts of LLMs. We categorize these contexts into two scenarios: Gray-Box and Black-Box. In a Black-Box scenario, the LLM provides only the generated text upon request, without additional information. Conversely, a Gray-Box scenario allows access to more detailed output, such as token probability information. In our experiments, GPT-3.5 falls into the Gray-Box category, as the OpenAI API enables retrieval of the top 5 token log probabilities, whereas other models are Black-Box ones. Furthermore, all experiments adhere to the sensitivity settings mentioned in Section 4.

5.1 Gray-Box Probability Weighting

For each question q, the requests $r_{forward}$ and $r_{backward}$ are:

$$r_{forward} = \{(s_i^f, c_i^f) \mid i = 1, 2, \ldots, k\} \quad (8)$$

$$r_{backward} = \{(s_j^b, c_j^b) \mid j = 1, 2, \ldots, k\} \quad (9)$$

Let function $p(\cdot)$ represents the probability of a token generated by the LLM. For instance, $p(s_3^f)$ represents the probability that the model selects the third option symbol of $r_{forward}$. We calculate the weighted probability for each option content c_i^f in the first query set $r_{forward}$. The weighted probability of a specific option content c_i^f is derived by integrating the probabilities of its corresponding symbol s_i^f in $r_{forward}$ with the symbol s_j^b in the second query set $r_{backward}$. The formulation of this computation is as follows:

$$P_{c_i^f}^{weighted} = p(s_i^f) \times p(s_j^b) \quad \text{where } c_i^f = c_j^b \quad (10)$$

The final choice is $c_{i^*}^f$, the option content with the highest weighted probability, determined by:

$$i^* = \operatorname*{argmax}_i P_{c_i^f}^{weighted}, \quad (11)$$

where f^* maximizes $P_{c_i^f}^{weighted}$.

Method	Setting	ARC	HellaSwag	MMLU	Winogrande	MathQA	OpenBookQA
Weighting	Token	**77.60** (+2.36)	**79.94** (+1.20)	**60.52** (+2.23)	56.67 (+2.21)	17.09 (+3.02)	**75.00** (+3.10)
	Order	**78.80** (+3.00)	**80.58** (+1.82)	**60.93** (+2.57)	59.04 (+4.06)	17.42 (+3.22)	**75.00** (+4.40)
	Both	**80.26** (+2.27)	**81.27** (+2.58)	**61.83** (+2.48)	**59.12** (+4.62)	16.08 (+3.25)	**77.80** (+4.10)
Calibration	Token	75.62 (+0.39)	79.35 (+0.61)	59.49 (+1.20)	**59.31** (+4.85)	**23.79** (+9.72)	72.40 (+0.50)
	Order	76.22 (+0.43)	79.32 (+0.56)	59.41 (+1.05)	**59.71** (+4.74)	**22.60** (+8.39)	70.60 (+0.00)
	Both	78.07 (+0.09)	79.30 (+0.61)	60.62 (+1.27)	58.84 (+4.34)	**22.41** (+9.58)	74.30 (+0.60)

Table 3: Results of gray-box methods of GPT-3.5 model. Accuracy is presented in percentage format, with the highest results in each setting **bolded**. Differences from the original results are shown in parentheses, with positive improvements highlighted in blue, indicating enhanced performance following our method.

5.2 Gray-Box Probability Calibration

Due to the sensitivities of LLMs to both the order and tokens in MCQs, their outputs frequently show biases, leading to preferences for specific options. To address this issue and promote a fairer and more accurate answer selection process, we calibrate the output probabilities. This calibration aims to enhance the precision of which the model selects answers.

Let the output distributions for each option symbol in $r_{forward}$ and $r_{backward}$ are denoted by $D_{forward}$ and $D_{backward}$, respectively, and are formulated as follows:

$$D_{forward} = \{p_d(s_i^f) \mid i = 1, 2, \dots, k\} \quad (12)$$

$$D_{backward} = \{p_d(s_j^b) \mid j = 1, 2, \dots, k\} \quad (13)$$

where $p_d(s_i)$ represents the probability distribution of option symbol s_i , defined by:

$$p_d(s_i) = \frac{\text{count}(s_i)}{N} \quad (14)$$

Here, N denotes the total sample count, and count(s_i) indicates the number of samples for which the model selects s_i as the answer. Thus, $p_d(s_i)$ reflects the percentage of selections for s_i. For real-world applicability, we calculate these distributions using the validation set of each task.

To calculate the calibrated probabilities, we use the following formulations:

$$P^{calibrated}_{forward} = \left\{ \frac{p(s_i^f)}{p_d(s_i^f)} \mid i = 1, 2, \dots, k \right\} \quad (15)$$

$$P^{calibrated}_{backward} = \left\{ \frac{p(s_j^b)}{p_d(s_j^b)} \mid j = 1, 2, \dots, k \right\} \quad (16)$$

Here, $P^{calibrated}_{forward}$ and $P^{calibrated}_{backward}$ represent the sets of calibrated probabilities for each option symbol in $r_{forward}$ and $r_{backward}$, respectively. The calibration process of $P^{calibrated}_{forward}$ involves dividing the original probability of selecting each symbol $p(s_i^f)$ by its corresponding output distribution probability $p_d(s_i^f)$, for $i = 1, 2, \dots, k$. This approach ensures that each option's probability is adjusted in light of its observed selection frequency, aiming to align the model's output more closely with an unbiased selection criterion.

Considering the three distinct sensitivity settings, we identify three specific distribution sets: $(D^{token}_{forward}, D^{token}_{backward})$, $(D^{order}_{forward}, D^{order}_{backward})$, and $(D^{both}_{forward}, D^{both}_{backward})$. These distributions underpin our calibration strategy, allowing us to adjust the model's outputs to reduce bias and enhance answer accuracy across different sensitivity contexts.

5.3 Black-Box Two-Hop Strategy

In practical applications, we often encounter black-box scenarios while using commercial LLM APIs. To mitigate the impact of model sensitivity in these situations, we propose a black-box two-hop strategy that leverages the model's output distributions $D_{forward}$. Given the constraints of black-box scenarios, where recalculating the token probability $p(s_i)$ is impossible, we adopt an alternative strategy. Our approach intentionally avoids selecting the most biased option symbols in the first request $r_{forward}$, opting for responses from $r_{backward}$ instead. Firstly, we identify the most probable option symbol $s^f_{i^*}$ based on the distribution $D_{forward}$, using the equation:

$$i^* = \underset{i}{\text{argmax}}\, p_d(s_i^f), \quad (17)$$

where $p_d(s_i^f)$ denotes the distribution probability of selecting symbol s_i^f from $r_{forward}$. Subsequently, the two-hop strategy is implemented as follows:

$$\text{Final Selection} = \begin{cases} c^f_{j^*_f} & \text{if } i^* \neq j^*_f, \\ c^b_{j^*_b} & \text{if } i^* = j^*_f, \end{cases} \quad (18)$$

Model	Setting	ARC	HellaSwag	MMLU	Winogrande	MathQA	OpenBookQA
PaLM 2	Token	82.15 (+0.00)	91.46 (+0.39)	64.52 (+0.20)	66.54 (-0.95)	31.52 (+0.65)	85.40 (+0.70)
	Order	81.63 (+0.34)	91.55 (+0.69)	64.09 (+0.39)	71.43 (-1.50)	31.69 (+1.51)	85.60 (+0.20)
	Both	83.00 (+0.69)	92.24 (+0.12)	64.05 (+0.59)	62.27 (-5.80)	31.62 (+1.07)	86.20 (-0.20)
Gemini Pro	Token	85.67 (+0.52)	78.77 (-0.32)	65.91 (+0.16)	62.43 (+1.14)	27.27 (+0.89)	83.00 (-0.10)
	Order	85.84 (+1.33)	79.70 (+0.66)	65.75 (+0.95)	59.43 (-1.03)	26.37 (+0.05)	83.20 (+0.80)
	Both	85.67 (+1.24)	80.31 (+1.54)	65.88 (+1.50)	59.27 (-1.18)	26.67 (+0.02)	84.40 (+1.00)
GPT-3.5	Token	76.74 (+1.50)	80.90 (+2.16)	59.69 (+1.40)	53.99 (-0.47)	12.23 (-1.84)	72.60 (+0.70)
	Order	76.39 (+0.60)	81.29 (+2.53)	59.44 (+1.08)	51.62 (-3.35)	12.09 (-2.11)	72.00 (+1.40)
	Both	78.03 (+0.04)	80.81 (+2.12)	60.47 (+1.12)	49.25 (-5.25)	11.56 (-1.27)	73.80 (+0.10)
LLaMA2-7B	Token	41.29 (+3.22)	37.46 (-1.75)	32.27 (+0.05)	45.94 (-0.71)	15.61 (+0.30)	32.60 (+3.00)
	Order	41.29 (+3.91)	47.24 (+7.94)	32.35 (+1.97)	46.72 (-0.28)	15.61 (-0.57)	32.60 (-0.30)
	Both	41.29 (+1.97)	45.02 (+3.85)	32.32 (+0.91)	46.33 (-0.39)	15.61 (-1.27)	32.60 (-1.10)
LLaMA2-13B	Token	45.24 (-0.39)	41.63 (+3.61)	39.19 (+2.23)	42.30 (-1.70)	19.13 (+0.22)	35.20 (-2.50)
	Order	47.47 (+1.50)	39.41 (+1.30)	37.74 (+1.07)	41.75 (-2.05)	18.76 (+0.23)	43.20 (+3.80)
	Both	48.76 (+2.58)	39.17 (+1.84)	39.40 (+2.62)	44.20 (-1.22)	19.66 (-0.10)	43.20 (+1.30)
LLaMA2-70B	Token	61.55 (+1.37)	62.21 (+3.55)	47.29 (+2.34)	47.36 (-0.36)	24.36 (+1.22)	57.80 (-0.20)
	Order	61.03 (+0.86)	58.84 (-0.01)	46.12 (-0.17)	47.36 (-1.26)	23.35 (+0.10)	57.00 (+1.90)
	Both	64.72 (+3.35)	66.52 (+2.10)	49.03 (+1.71)	47.36 (-0.24)	23.95 (-0.59)	60.80 (+0.40)

Table 4: Results of the black-box method. Accuracy is presented in percentage format. Differences from the baseline results are indicated in parentheses: improvements are highlighted in blue, signifying enhanced performance due to our method, while declines are marked in red, indicating a decrease in performance in those scenarios.

where we select $c^f_{j^*_f}$ from $r_{forward}$ if it does not exhibit bias most. Otherwise, we opt for $c^b_{j^*_b}$ as our final answer. Here, j^*_f and j^*_b are determined by:

$$j^*_f = \underset{j}{\text{argmax}}\, p(s^f_j), \tag{19}$$

$$j^*_b = \underset{j}{\text{argmax}}\, p(s^b_j), \tag{20}$$

where j^*_f, j^*_b indicate the indices of the symbols with the highest probabilities in $r_{forward}$, $r_{backward}$, respectively.

This method aims to utilize responses that potentially minimize bias by considering the model's preference patterns indicated by $D_{forward}$, thereby ensuring the accuracy of selections.

6 Experiment Results

6.1 Gray-Box Results

Tables 3 and 4 show the results of our methods. In the gray-box scenario, only GPT-3.5 is included since other models do not provide the information of token probability information. Conversely, in the black-box scenario, all models are considered in our experiment. In the subsequent analysis, we compare the performance improvements achieved by our methods against the baseline established in Section 4, aiming to underscore the enhancements or limitations observed across tasks and models.

As Table 3 illustrates, gray-box methods, including both probability weighting and calibration approaches, significantly improve performance across six distinct tasks under three sensitivity settings. Notably, the probability weighting method demonstrates considerable enhancements in all scenarios, surpassing the baseline. It benefits not only more challenging tasks such as MathQA, Winogrande, and MMLU but also shows improvements in easier tasks. Interestingly, the probability calibration method outperforms the weighting method in two specific tasks out of the six: Winogrande and MathQA. These tasks are unique in their format; Winogrande presents only two options, whereas MathQA offers five options per question. We speculate that the number of options may influence the LLM's preference distribution, thereby affecting the performance of different methods.

6.2 Black-Box Results

Table 4 displays the results of the black-box method applied to various models, sensitivity settings, and tasks. Notably, the stronger models, PaLM 2 and Gemini Pro, show significant benefits from the two-hop strategy. They improved in five out of six tasks, with Winogrande being the only exception. Similarly , GPT-3.5 also shows improvements in most tasks, succeeding in four out of six. The exceptions are Winogrande and MathQA, with MathQA noted as the most challenging one across all tasks. The LLaMA 2 models, spanning the 7B, 13B, and 70B variants, improve in half of the evaluated tasks. Their performance is consistent across model sizes. They excel in ARC Challenge, HellaSwag, and MMLU but face challenges in the other three tasks.

A noteworthy observation is that all models, re-

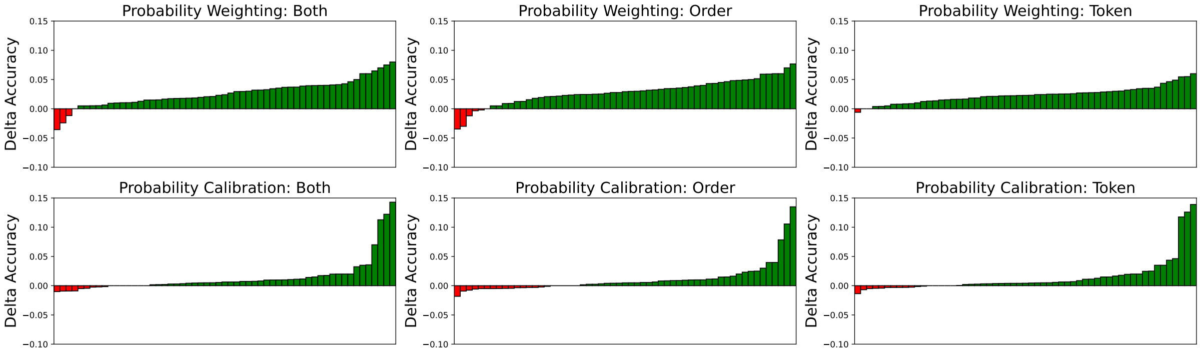

Figure 2: Accuracy Difference Distribution Across 57 MMLU Subtasks For The GPT-3.5 Model in the Gray-Box Scenario: Subtasks are sorted by the difference in accuracy from low to high, indicating that subtasks towards the right benefit more from our methodology. Improvements are marked in green, whereas declines in performance are highlighted in red. The top three diagrams present outcomes from the probability weighting method across three sensitivity settings, while the bottom three diagrams illustrate the effects of the probability calibration method.

gardless of their capability, exhibit reduced performance on the Winogrande task after applying our two-hop strategy. This includes both the high-end models like PaLM 2 and Gemini Pro, as well as the smaller scale LLaMA 2-7B model. The reasons for this decline are not immediately apparent, as factors such as model strength, task difficulty, and specific sensitivity to Winogrande do not directly explain the reduced effectiveness. Winogrande stands out due to its unique characteristics: it offers only two options per question and employs a cloze-test format rather than standard question-answering. We hypothesize that the limited number of options or the specific task type might alter the LLM's preference distribution, impacting the efficacy of our black-box strategy.

6.3 Breakdown MMLU Subtasks

To gain deeper insights, we conducted a detailed breakdown of the MMLU's 57 subtasks, examining closely how each method we proposed affects these subtasks. Figure 2 offers a comprehensive view of how the MMLU's 57 subtasks respond to both the probability weighting and calibration methods within a gray-box scenario. Consistent with the findings reported in Table 3, most of subtasks improve after applying our proposed methods. Specifically, within the probability weighting analysis, declines are observed in only 1, 6, and 3 subtasks across the *token*, *order*, and *both* settings, respectively. This translates to an average of merely about 6% of tasks not deriving benefits from the weighting method. Upon closer examination, *virology* emerges as the subtask experiencing a decline across all three sensitivity settings. Among subtasks with notable decreases, *machine learning* in the both setting shows a 3.57% drop, while *moral scenarios* and *business ethics* in the order setting decline by 3.46% and 3%, respectively.

Regarding the probability calibration method, on average, more than 78% of the subtasks improved with our approach, with over 30% of them having at least a 1% increase in accuracy. Recall that, in Table 3, the calibration method significantly outperforms the weighting method in the MathQA task. This trend extends across MMLU subtasks, with STEM-related tasks showing the most substantial gains. For instance, in the *both* setting, the top beneficiaries include *elementary mathematics*, *high school mathematics*, *college physics*, and *college chemistry*, with improvements of 14.29%, 12.22%, 11.27%, and 7.00%, respectively, outshining other subtasks. This phenomenon is shown in the bottom three diagrams of Figure 2. Due to space constraints, detailed breakdowns of the gray-box method are presented in Appendix E, within Table 17 and 18. Figure 6, 7, and 8 in Appendix F displays the results of the black-box two-hop strategy, with LLMs, where only generated text is accessible. Despite this limitation, more than half of the MMLU subtasks show improvement after our method's application. This enhancement is observed across various models, from the strongest to smaller ones like the 7B and 13B models.

6.4 Cost Analysis

Our method prioritizes cost-effectiveness by minimizing the need for numerous permutations or voting on costly chain-of-thought (CoT) candidates. For the probability weighting method, each question q needs two requests to calculate the weighted probability. In contrast, the probability calibration and gray-box methods require a validation set of approximately 200 samples to compute the distributions $D_{forward}$ and $D_{backward}$. Calibration of either $r_{forward}$ or $r_{backward}$ alone requires just one request per question; The black-box method also demands two requests per question q. Furthermore, the total expense for all experiments conducted in this study was under $400 USD, covering six models and six benchmarks. Notably, the use of PaLM 2 and Gemini Pro was temporarily free. For specific costs associated with the OpenAI API and Azure AI Studio, please refer to the official documentations.

7 Conclusion

This study investigate into the effects of token and order sensitivity on LLMs when addressing selection problems, incorporating an empirical analysis of both powerful commercial LLMs such as Gemini Pro and GPT-3.5 and open-sources models like LLaMA 2. By concentrating on zero-shot settings, we aim to isolate and better understand biases that previous works identified in in-context demonstrations, thereby offering a clearer perspective on how these sensitivities influence LLM decision-making processes. Our findings underscore the significance of task difficulty as a crucial determinant of sensitivity impact on LLM performance.

Moreover, we introduce cost-effective mitigation strategies, including gray-box and black-box approaches, tailored for practical application scenarios. The results demonstrate that our gray-box methods, namely probability weighting and probability calibration, outperform baselines with minimal additional expenditure, contrasting with more complex methods like majority voting. Additionally, our two-hop strategy for black-box scenarios proves to be effective in a significant portion of tasks. We anticipate that our contributions will aid future research in enhancing the robustness of LLMs across various types of selection problem applications.

8 Limitation

While this study contributes valuable insights into mitigating selection biases in LLMs, we acknowledge several limitations that warrant consideration. Firstly, the gray-box strategies proposed for alleviating selection biases may encounter constraints when applied to certain black-box LLM APIs. The efficacy of these strategies heavily relies on the availability of probability information, which may be restricted in externally hosted APIs.

Secondly, the exploration of mitigation strategies primarily focuses on the gray-box and black-box settings, leaving the examination of further mitigation strategies in white-box open-source models unexplored, and we recognize it as a potential avenue for future research. Investigating mitigation strategies within white-box open-source models could provide a more comprehensive understanding of how selection biases manifest and can be addressed in models where internal workings are transparent.

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References

Aida Amini, Saadia Gabriel, Shanchuan Lin, Rik Koncel-Kedziorski, Yejin Choi, and Hannaneh Hajishirzi. 2019. Mathqa: Towards interpretable math word problem solving with operation-based formalisms. *ArXiv*, abs/1905.13319.

Rohan Anil, Andrew M Dai, Orhan Firat, Melvin Johnson, Dmitry Lepikhin, Alexandre Passos, Siamak Shakeri, Emanuel Taropa, Paige Bailey, Zhifeng Chen, et al. 2023. Palm 2 technical report. *arXiv preprint arXiv:2305.10403*.

Edward Beeching, Clémentine Fourrier, Nathan Habib, Sheon Han, Nathan Lambert, Nazneen Rajani, Omar Sanseviero, Lewis Tunstall, and Thomas Wolf. 2023. Open llm leaderboard. `https://huggingface.co/spaces/HuggingFaceH4/open_llm_leaderboard`.

Peter Clark, Isaac Cowhey, Oren Etzioni, Tushar Khot, Ashish Sabharwal, Carissa Schoenick, and Oyvind Tafjord. 2018. Think you have solved question answering? try arc, the ai2 reasoning challenge.

Yu Fei, Yifan Hou, Zeming Chen, and Antoine Bosselut. 2023. Mitigating label biases for in-context learning. In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 14014–14031, Toronto, Canada. Association for Computational Linguistics.

Leo Gao, Jonathan Tow, Baber Abbasi, Stella Biderman, Sid Black, Anthony DiPofi, Charles Foster, Laurence Golding, Jeffrey Hsu, Alain Le Noac'h, et al. 2023. A framework for few-shot language model evaluation.

Google Gemini Team. 2023. Gemini: A family of highly capable multimodal models. *ArXiv*, abs/2312.11805.

Dan Hendrycks, Collin Burns, Steven Basart, Andy Zou, Mantas Mazeika, Dawn Song, and Jacob Steinhardt. 2021. Measuring massive multitask language understanding. In *International Conference on Learning Representations*.

Todor Mihaylov, Peter Clark, Tushar Khot, and Ashish Sabharwal. 2018. Can a suit of armor conduct electricity? a new dataset for open book question answering. In *Proceedings of the 2018 Conference on Empirical Methods in Natural Language Processing*, pages 2381–2391, Brussels, Belgium. Association for Computational Linguistics.

OpenAI. 2022. Introducing ChatGPT. https://openai.com/blog/chatgpt.

OpenAI. 2023. Gpt-4 technical report. *ArXiv*.

Pouya Pezeshkpour and Estevam Hruschka. 2023. Large language models sensitivity to the order of options in multiple-choice questions. *ArXiv*, abs/2308.11483.

Joshua Robinson and David Wingate. 2023. Leveraging large language models for multiple choice question answering. In *The Eleventh International Conference on Learning Representations*.

Keisuke Sakaguchi, Ronan Le Bras, Chandra Bhagavatula, and Yejin Choi. 2019. WINOGRANDE: an adversarial winograd schema challenge at scale.

Chenhui Shen, Liying Cheng, Xuan-Phi Nguyen, Yang You, and Lidong Bing. 2023. Large language models are not yet human-level evaluators for abstractive summarization. In *Findings of the Association for Computational Linguistics: EMNLP 2023*, pages 4215–4233, Singapore. Association for Computational Linguistics.

Chenglei Si, Dan Friedman, Nitish Joshi, Shi Feng, Danqi Chen, and He He. 2023. Measuring inductive biases of in-context learning with underspecified demonstrations. In *Proceedings of the 61st Annual Meeting of the Association for Computational Linguistics (Volume 1: Long Papers)*, pages 11289–11310, Toronto, Canada. Association for Computational Linguistics.

Hugo Touvron, Louis Martin, Kevin Stone, Peter Albert, Amjad Almahairi, Yasmine Babaei, Nikolay Bashlykov, Soumya Batra, Prajjwal Bhargava, Shruti Bhosale, et al. 2023. Llama 2: Open foundation and fine-tuned chat models.

Peiyi Wang, Lei Li, Liang Chen, Dawei Zhu, Binghuai Lin, Yunbo Cao, Qi Liu, Tianyu Liu, and Zhifang Sui. 2023. Large language models are not fair evaluators. *ArXiv*, abs/2305.17926.

Rowan Zellers, Ari Holtzman, Yonatan Bisk, Ali Farhadi, and Yejin Choi. 2019. HellaSwag: Can a machine really finish your sentence? In *Proceedings of the 57th Annual Meeting of the Association for Computational Linguistics*, pages 4791–4800, Florence, Italy. Association for Computational Linguistics.

Tony Zhao, Eric Wallace, Shi Feng, Dan Klein, and Sameer Singh. 2021. Calibrate before use: Improving few-shot performance of language models. In *International Conference on Machine Learning*.

Chujie Zheng, Hao Zhou, Fandong Meng, Jie Zhou, and Minlie Huang. 2024. Large language models are not robust multiple choice selectors. In *The Twelfth International Conference on Learning Representations*.

Lianmin Zheng, Wei-Lin Chiang, Ying Sheng, Siyuan Zhuang, Zhanghao Wu, Yonghao Zhuang, Zi Lin, Zhuohan Li, Dacheng Li, Eric Xing, Hao Zhang, Joseph E Gonzalez, and Ion Stoica. 2023. Judging llm-as-a-judge with mt-bench and chatbot arena. In *Advances in Neural Information Processing Systems*, volume 36, pages 46595–46623.

A Data statistics details

Table 5 shows the data statistics details across six tasks: ARC-Challenge, HellaSwag, MMLU, Winogrande, MathQA, and OpenBookQA.

Tasks	**# Samples**	**# Options**
Winogrande	1,267	2
ARC-Challenge	1,165	4
HellaSwag	10,042	4
MMLU	14,042	4
OpenBookQA	500	4
MathQA	2,985	5

Table 5: Data statistics of our benchmarks.

B Prompt templates

We list all the prompt templates used in our experiments, including three different sensitivity settings: *token*, *order*, and *both*. These templates are presented in Figures 3, 4, and 5, corresponding to each setting respectively.

C Detailed Sensitivity Experiment Results

Tables 6 through 11 provide detailed experimental results for the MMLU, covering its 57 subtasks for each of the following models: PaLM 2, Gemini Pro, GPT-3.5, LLaMA 2 7B, LLaMA 2 13B, and LLaMA 2 70B, respectively.

D LLMs' Option proportion statistics

Table 12 through 16 provide detailed information on the tendency of each option and the ground truth label proportion across five datasets: HellaSwag, MMLU, Winogrande, MathQA, and OpenBookQA.

E Gray-Box Results of MMLU Subtasks

Tables 17 and 18 detail the results for the MMLU's 57 subtasks following the application of our gray-box strategies, including probability weighting and calibration.

F Black-Box Results of MMLU Subtasks

Figure 6, 7 and 8 show the distribution of accuracy differences resulting from the black-box approach, specifically within the *token*, *order* and *both* sensitivity settings.

```
[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice A]
convolutional networks
[The end of choice A]

[The start of choice B]
graph networks
[The end of choice B]

[The start of choice C]
fully connected networks
[The end of choice C]

[The start of choice D]
RBF networks
[The end of choice D]
```

```
[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice D]
convolutional networks
[The end of choice D]

[The start of choice C]
graph networks
[The end of choice C]

[The start of choice B]
fully connected networks
[The end of choice B]

[The start of choice A]
RBF networks
[The end of choice A]
```

Figure 3: Prompt template illustrating the *token* sensitivity setting for each question q. The upper part represents $r_{forward}$, and the lower part corresponds to $r_{backward}$. Option symbols are highlighted in blue, while both the question text and option contents are highlighted in orange. Other text shown in black remains consistent across questions.

[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice A]
convolutional networks
[The end of choice A]

[The start of choice B]
graph networks
[The end of choice B]

[The start of choice C]
fully connected networks
[The end of choice C]

[The start of choice D]
RBF networks
[The end of choice D]

[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice D]
RBF networks
[The end of choice D]

[The start of choice C]
fully connected networks
[The end of choice C]

[The start of choice B]
graph networks
[The end of choice B]

[The start of choice A]
convolutional networks
[The end of choice A]

Figure 4: Prompt template illustrating the *order* sensitivity setting for each question q. The upper part represents $r_{forward}$, and the lower part corresponds to $r_{backward}$. Option symbols are highlighted in blue, while both the question text and option contents are highlighted in orange. Other text shown in black remains consistent across questions.

```
[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice A]
convolutional networks
[The end of choice A]

[The start of choice B]
graph networks
[The end of choice B]

[The start of choice C]
fully connected networks
[The end of choice C]

[The start of choice D]
RBF networks
[The end of choice D]
```

```
[System]
Please carefully read the following questions and choices. Select the most suitable one. Output your final verdict by strictly following this prompt: Indicate your choice by placing it inside double square brackets, with a single character representing the chosen option.For example, [[<single_character>]].

[The start of question]
As of 2020, which architecture is best for classifying high-resolution images?
[The end of question]

[The start of choice A]
RBF networks
[The end of choice A]

[The start of choice B]
fully connected networks
[The end of choice B]

[The start of choice C]
graph networks
[The end of choice C]

[The start of choice D]
convolutional networks
[The end of choice D]
```

Figure 5: Prompt template illustrating the *both* sensitivity setting for each question q. The upper part represents $r_{forward}$, and the lower part corresponds to $r_{backward}$. Option symbols are highlighted in blue, while both the question text and option contents are highlighted in orange. Other text shown in black remains consistent across questions.

Subtask	#sample	Token		Order		Both	
		Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate
abstract_algebra	100	32.0	15.0	32.5	47.0	33.5	34.0
anatomy	135	64.4	11.1	62.9	26.7	62.2	29.6
astronomy	152	73.7	12.5	74.3	28.9	74.3	28.3
business_ethics	100	75.0	9.0	71.0	27.0	72.5	26.0
clinical_knowledge	265	72.6	8.3	71.7	23.4	71.3	25.7
college_biology	144	81.6	5.6	81.3	16.0	79.9	20.1
college_chemistry	100	53.0	17.0	51.5	40.0	50.0	44.0
college_computer_science	100	44.0	20.0	44.0	38.0	42.0	46.0
college_mathematics	100	32.0	27.0	32.0	41.0	29.5	54.0
college_medicine	173	57.5	11.0	58.1	28.3	57.8	33.5
college_physics	102	48.5	19.6	44.6	40.2	44.6	39.2
computer_security	100	74.5	7.0	76.5	14.0	75.5	21.0
conceptual_physics	235	63.8	12.8	60.2	26.8	59.6	31.9
econometrics	114	48.2	23.7	47.4	37.7	50.9	41.2
electrical_engineering	145	61.0	11.0	61.7	37.2	57.2	42.1
elementary_mathematics	378	44.3	21.2	45.8	52.6	44.4	55.8
formal_logic	126	51.2	31.7	49.6	42.9	46.8	46.8
global_facts	100	34.5	26.0	40.5	50.0	38.5	56.0
high_school_biology	310	81.0	7.1	78.7	15.5	79.7	17.4
high_school_chemistry	203	56.9	17.7	54.2	36.0	54.4	40.9
high_school_computer_science	100	69.5	16.0	72.0	25.0	70.5	24.0
high_school_european_history	165	77.6	6.1	76.4	15.8	78.5	15.8
high_school_geography	198	82.8	8.1	81.8	12.6	80.8	14.6
high_school_government_and_politics	193	90.7	5.2	90.4	7.8	90.4	7.8
high_school_macroeconomics	390	65.1	11.5	64.0	24.6	63.6	27.2
high_school_mathematics	270	31.1	31.5	30.9	51.5	30.6	63.3
high_school_microeconomics	238	76.5	8.4	76.1	18.5	75.8	19.7
high_school_physics	151	36.8	19.2	37.7	41.7	37.4	42.4
high_school_psychology	545	88.6	3.7	86.8	11.6	87.4	11.7
high_school_statistics	216	58.3	15.7	54.2	38.9	52.1	42.1
high_school_us_history	204	80.9	7.4	80.4	18.1	81.1	18.6
high_school_world_history	237	83.3	3.4	82.7	11.8	85.2	13.5
human_aging	223	69.7	9.0	70.4	19.3	68.4	22.0
human_sexuality	131	75.2	9.9	75.9	23.7	74.8	29.0
international_law	121	80.2	3.3	81.0	19.8	79.3	21.5
jurisprudence	108	81.0	3.7	80.1	17.6	81.0	13.0
logical_fallacies	163	81.9	4.3	82.5	13.5	81.3	16.0
machine_learning	112	42.4	17.0	44.2	31.3	44.2	25.9
management	103	86.4	8.7	85.0	11.7	85.4	13.6
marketing	234	86.1	2.6	87.4	9.4	86.5	11.5
medical_genetics	100	69.0	16.0	68.5	20.0	70.5	26.0
miscellaneous	783	82.0	6.9	82.4	13.0	82.2	13.4
moral_disputes	346	70.4	9.8	70.1	21.7	69.7	22.5
moral_scenarios	895	32.1	79.6	31.3	16.2	34.9	76.1
nutrition	306	67.0	9.5	66.8	24.8	67.2	25.8
philosophy	311	70.6	7.7	69.0	24.1	69.1	23.5
prehistory	324	75.8	10.5	75.9	20.4	75.3	24.1
professional_accounting	282	50.9	18.4	51.6	34.8	50.0	39.4
professional_law	1534	46.7	17.7	45.6	41.9	44.4	49.1
professional_medicine	272	69.3	11.4	66.7	28.7	65.4	33.1
professional_psychology	612	70.8	8.7	69.4	20.8	69.0	24.3
public_relations	110	71.4	7.3	68.6	26.4	68.2	28.2
security_studies	245	75.9	4.5	75.1	25.3	76.7	26.1
sociology	201	87.3	4.5	84.6	15.4	83.1	16.9
us_foreign_policy	100	86.5	9.0	86.5	11.0	83.5	16.0
virology	166	49.4	10.8	51.5	19.9	50.0	27.1
world_religions	171	82.5	2.9	83.6	11.7	83.0	11.7

Table 6: Results of the sensitivity experiment across 57 MMLU subtasks for PaLM 2, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

Subtask	#sample	Token		Order		Both	
		Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate
abstract_algebra	100	35.0	51.0	33.0	73.0	32.5	78.0
anatomy	135	60.0	18.5	61.1	34.1	60.0	31.1
astronomy	152	76.9	12.5	75.7	21.7	74.3	26.9
business_ethics	100	62.5	14.0	64.5	38.0	65.5	38.0
clinical_knowledge	265	74.3	12.8	74.2	23.4	72.8	27.9
college_biology	144	81.3	11.8	81.9	20.1	81.3	22.9
college_chemistry	100	46.5	28.0	49.0	39.0	47.5	56.0
college_computer_science	100	52.5	26.0	51.5	48.0	47.5	52.0
college_mathematics	100	33.5	39.0	36.5	52.0	37.0	64.0
college_medicine	173	67.9	12.1	66.2	31.2	63.9	32.9
college_physics	102	37.7	34.3	41.2	43.1	41.7	43.1
computer_security	100	72.5	10.0	73.5	21.0	74.5	21.0
conceptual_physics	235	60.2	14.9	57.4	31.9	59.4	36.2
econometrics	114	44.3	32.5	45.2	48.2	45.2	50.9
electrical_engineering	145	63.4	20.7	61.0	40.7	61.7	42.8
elementary_mathematics	378	45.8	27.0	46.0	53.2	45.8	54.8
formal_logic	126	47.2	17.5	47.6	46.8	47.2	51.6
global_facts	100	43.5	40.0	39.5	78.0	40.0	66.0
high_school_biology	310	82.1	10.6	82.7	16.1	81.1	19.0
high_school_chemistry	203	55.7	25.6	53.4	38.9	51.7	44.3
high_school_computer_science	100	76.0	13.0	73.5	26.0	75.5	26.0
high_school_european_history	165	80.9	10.9	79.1	15.8	79.7	17.0
high_school_geography	198	78.8	13.1	83.3	15.7	79.8	22.2
high_school_government_and_politics	193	88.3	8.3	89.9	10.4	89.1	13.5
high_school_macroeconomics	390	66.9	10.8	66.3	30.0	65.3	31.5
high_school_mathematics	270	34.4	33.3	35.6	55.6	33.9	66.3
high_school_microeconomics	238	76.3	15.1	75.8	21.4	75.6	27.3
high_school_physics	151	38.7	33.1	40.4	48.3	40.4	53.6
high_school_psychology	545	85.6	7.2	85.7	10.8	85.3	14.3
high_school_statistics	216	59.3	20.8	56.7	41.7	53.0	47.7
high_school_us_history	204	83.6	10.3	83.8	13.2	83.8	16.2
high_school_world_history	237	86.3	8.4	84.2	16.0	83.8	18.6
human_aging	223	71.3	9.9	69.3	25.1	69.5	29.6
human_sexuality	131	77.5	14.5	74.0	20.6	74.8	26.7
international_law	121	78.5	14.0	80.2	21.5	80.2	24.0
jurisprudence	108	78.7	13.9	78.7	18.5	75.0	22.2
logical_fallacies	163	79.1	12.3	76.4	22.7	77.0	19.0
machine_learning	112	41.9	27.7	43.3	52.7	47.3	58.0
management	103	83.0	6.8	80.1	17.5	80.6	20.4
marketing	234	88.0	6.0	88.7	12.4	88.2	13.7
medical_genetics	100	75.0	12.0	73.0	22.0	72.5	25.0
miscellaneous	783	83.4	7.3	83.5	13.2	84.0	15.5
moral_disputes	346	67.8	14.7	63.7	33.8	66.8	34.4
moral_scenarios	895	40.9	51.4	35.6	86.5	36.3	90.3
nutrition	306	73.5	14.4	74.7	22.9	73.0	26.8
philosophy	311	74.3	13.5	72.0	27.7	70.6	28.9
prehistory	324	75.9	12.0	74.7	17.6	75.0	21.3
professional_accounting	282	51.6	27.0	50.0	42.2	50.0	45.7
professional_law	1534	51.1	26.5	50.1	37.5	49.4	50.1
professional_medicine	272	75.0	12.9	73.7	23.5	69.1	30.9
professional_psychology	612	69.9	15.4	68.5	25.0	68.6	25.8
public_relations	110	66.8	16.4	65.5	30.9	63.6	30.0
security_studies	245	73.9	16.7	73.5	20.0	71.8	28.2
sociology	201	83.6	8.0	82.1	13.9	81.8	16.4
us_foreign_policy	100	86.5	7.0	83.5	16.0	84.0	19.0
virology	166	49.7	12.7	48.8	23.5	49.7	22.9
world_religions	171	83.9	7.6	83.3	12.3	83.0	11.7

Table 7: Results of the sensitivity experiment across 57 MMLU subtasks for Gemini Pro, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

		Token		Order		Both	
Subtask	#sample	Avg.	Fluct.	Avg.	Fluct.	Avg.	Fluct.
		Acc	Rate	Acc	Rate	Acc	Rate
abstract_algebra	100	25.5	17.0	32.5	25.0	31.0	42.0
anatomy	135	63.0	23.7	62.6	31.9	64.1	30.4
astronomy	152	71.7	20.4	69.1	32.2	70.1	31.6
business_ethics	100	57.5	29.0	64.0	39.0	62.5	36.0
clinical_knowledge	265	67.0	20.8	67.4	29.1	69.6	26.4
college_biology	144	69.8	23.6	72.9	27.1	71.9	25.7
college_chemistry	100	40.5	32.0	46.5	34.0	43.0	43.0
college_computer_science	100	49.5	30.0	45.0	38.0	47.5	37.0
college_mathematics	100	27.0	24.0	31.0	32.0	27.5	39.0
college_medicine	173	56.1	24.9	55.5	37.6	57.8	34.7
college_physics	102	29.4	20.6	35.8	30.4	34.3	46.1
computer_security	100	70.5	20.0	69.0	25.0	74.0	26.0
conceptual_physics	235	54.7	23.4	52.3	32.8	53.8	32.8
econometrics	114	37.7	29.8	37.3	43.9	37.3	43.0
electrical_engineering	145	56.6	22.8	57.6	30.3	55.5	35.2
elementary_mathematics	378	25.5	13.2	23.0	21.4	25.5	40.5
formal_logic	126	37.3	22.2	34.5	42.1	36.5	55.6
global_facts	100	38.0	50.0	34.5	37.0	34.0	57.0
high_school_biology	310	74.8	17.4	73.9	22.6	74.7	24.5
high_school_chemistry	203	47.5	25.6	46.8	32.0	50.5	36.0
high_school_computer_science	100	60.0	20.0	62.5	24.0	64.0	25.0
high_school_european_history	165	71.8	10.3	70.6	27.3	73.0	23.0
high_school_geography	198	79.0	17.2	77.8	19.2	78.0	16.2
high_school_government_and_politics	193	86.8	5.2	85.5	8.8	87.6	8.8
high_school_macroeconomics	390	58.1	22.8	56.7	39.2	57.9	39.0
high_school_mathematics	270	16.3	20.4	16.1	27.4	16.1	47.0
high_school_microeconomics	238	65.3	19.7	66.0	34.9	66.4	31.9
high_school_physics	151	29.8	23.8	25.2	34.4	30.1	46.4
high_school_psychology	545	82.1	13.6	81.6	21.1	83.6	15.6
high_school_statistics	216	43.3	27.8	42.4	39.4	43.8	47.7
high_school_us_history	204	77.7	9.8	77.9	19.1	78.4	19.1
high_school_world_history	237	78.5	10.1	77.6	15.6	79.3	17.7
human_aging	223	67.7	21.1	66.8	25.1	67.7	23.8
human_sexuality	131	72.9	18.3	73.3	25.2	74.0	23.7
international_law	121	73.1	11.6	74.8	24.0	74.8	22.3
jurisprudence	108	74.1	12.0	74.1	19.4	73.1	13.9
logical_fallacies	163	68.1	20.2	67.2	25.2	71.2	24.5
machine_learning	112	42.4	17.0	44.6	37.5	49.1	31.3
management	103	76.2	9.7	76.2	24.3	77.7	19.4
marketing	234	85.3	15.8	86.1	14.9	88.2	11.5
medical_genetics	100	68.5	21.0	69.0	25.0	73.0	24.0
miscellaneous	783	83.7	14.3	84.9	13.2	86.2	12.0
moral_disputes	346	65.8	22.5	65.6	30.9	64.7	33.5
moral_scenarios	895	21.6	74.7	21.5	67.6	22.0	31.2
nutrition	306	67.2	18.6	68.5	21.2	69.0	21.6
philosophy	311	65.9	21.9	67.0	27.7	67.8	28.9
prehistory	324	67.0	15.1	69.1	27.5	68.2	29.3
professional_accounting	282	42.6	30.9	44.5	40.1	44.9	40.8
professional_law	1534	45.3	26.4	45.1	35.0	46.1	33.5
professional_medicine	272	65.3	20.6	65.4	29.4	69.7	23.5
professional_psychology	612	63.3	19.4	63.6	27.6	64.2	24.7
public_relations	110	64.1	15.5	61.8	25.5	65.5	22.7
security_studies	245	64.1	18.8	66.7	29.4	63.7	34.7
sociology	201	80.3	14.9	79.4	17.4	79.1	20.4
us_foreign_policy	100	82.5	9.0	81.0	15.0	80.5	22.0
virology	166	49.4	20.5	50.0	25.3	48.8	23.5
world_religions	171	79.5	14.0	80.7	17.5	83.6	12.3

Table 8: Results of the sensitivity experiment across 57 MMLU subtasks for GPT-3.5, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

		Token		Order		Both	
Subtask	**#sample**	**Avg. Acc**	**Fluct. Rate**	**Avg. Acc**	**Fluct. Rate**	**Avg. Acc**	**Fluct. Rate**
abstract_algebra	100	23.5	59.0	15.0	26.0	20.5	77.0
anatomy	135	36.3	61.5	35.6	65.9	37.4	76.3
astronomy	152	36.8	52.6	29.3	73.0	32.2	75.7
business_ethics	100	33.0	54.0	31.0	56.0	33.0	63.0
clinical_knowledge	265	38.7	63.8	36.6	72.5	37.5	80.8
college_biology	144	37.5	58.3	31.3	71.5	33.0	75.0
college_chemistry	100	33.5	68.0	26.0	61.0	25.5	81.0
college_computer_science	100	19.0	51.0	20.0	52.0	23.0	74.0
college_mathematics	100	17.0	58.0	20.0	46.0	20.0	84.0
college_medicine	173	33.8	52.0	29.8	63.0	31.8	72.3
college_physics	102	17.2	68.6	16.7	47.1	15.7	80.4
computer_security	100	33.0	54.0	35.0	69.0	39.0	62.0
conceptual_physics	235	34.0	50.2	35.7	80.0	33.4	74.5
econometrics	114	16.2	44.7	18.4	53.5	19.7	62.3
electrical_engineering	145	33.8	51.7	29.7	77.9	30.7	81.4
elementary_mathematics	378	24.6	62.4	24.6	55.3	26.2	84.1
formal_logic	126	22.6	68.3	23.0	42.1	22.6	89.7
global_facts	100	36.5	57.0	33.5	56.0	32.0	67.0
high_school_biology	310	37.7	53.5	34.2	71.6	36.8	71.0
high_school_chemistry	203	26.8	65.5	24.9	66.0	26.1	83.3
high_school_computer_science	100	30.5	56.0	33.0	53.0	34.5	72.0
high_school_european_history	165	39.7	38.8	34.2	60.0	36.4	72.1
high_school_geography	198	38.4	46.5	35.9	72.2	36.4	76.3
high_school_government_and_politics	193	49.7	36.8	41.2	73.1	43.0	69.9
high_school_macroeconomics	390	35.5	56.2	30.4	67.2	32.9	73.6
high_school_mathematics	270	20.7	50.4	17.6	46.7	17.2	76.3
high_school_microeconomics	238	33.0	55.0	28.8	63.4	28.6	72.7
high_school_physics	151	26.2	65.6	24.8	53.0	24.2	83.4
high_school_psychology	545	47.2	48.4	38.6	70.3	42.0	71.0
high_school_statistics	216	27.5	61.1	21.5	53.2	20.8	75.5
high_school_us_history	204	32.1	42.2	30.6	61.3	33.1	73.0
high_school_world_history	237	37.6	40.1	39.9	61.2	39.7	68.4
human_aging	223	32.3	46.6	38.6	73.1	38.8	64.1
human_sexuality	131	17.9	26.7	17.6	33.6	20.6	33.6
international_law	121	47.5	46.3	48.3	66.1	51.7	55.4
jurisprudence	108	36.6	51.9	40.7	67.6	38.4	77.8
logical_fallacies	163	41.4	53.4	39.6	76.1	39.9	77.3
machine_learning	112	23.7	44.6	31.3	74.1	30.8	84.8
management	103	41.7	57.3	33.5	82.5	35.9	72.8
marketing	234	41.7	53.0	44.0	86.3	49.1	70.5
medical_genetics	100	30.5	60.0	31.0	84.0	32.5	76.0
miscellaneous	783	43.2	51.9	43.8	68.5	45.9	67.0
moral_disputes	346	29.3	44.2	28.5	73.7	30.5	69.7
moral_scenarios	895	6.0	15.8	6.0	2.0	5.9	31.3
nutrition	306	35.5	62.4	33.7	69.3	39.2	76.5
philosophy	311	40.0	49.5	36.7	76.8	40.0	67.5
prehistory	324	37.3	53.4	36.1	77.5	37.0	75.3
professional_accounting	282	26.2	56.4	27.7	64.9	27.5	72.0
professional_law	1534	28.3	30.9	26.7	53.1	25.1	59.6
professional_medicine	272	32.4	51.8	25.2	51.5	21.7	79.4
professional_psychology	612	33.2	50.7	32.7	71.7	34.2	67.0
public_relations	110	43.6	40.0	39.5	80.0	41.4	73.6
security_studies	245	40.0	36.7	32.4	82.0	32.7	81.2
sociology	201	46.0	39.3	40.8	73.1	44.8	69.7
us_foreign_policy	100	42.0	47.0	40.0	66.0	39.0	63.0
virology	166	34.3	51.2	31.6	77.7	30.7	65.1
world_religions	171	33.3	55.6	39.8	74.9	44.4	67.3

Table 9: Results of the sensitivity experiment across 57 MMLU subtasks for LLaMA 2 7B, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

Subtask	#sample	Token		Order		Both	
		Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate
abstract_algebra	100	26.5	7.0	25.5	35.0	26.0	29.0
anatomy	135	41.5	43.7	41.1	34.1	42.6	48.9
astronomy	152	38.5	38.2	45.1	42.8	39.8	50.7
business_ethics	100	37.0	47.0	38.0	36.0	36.0	55.0
clinical_knowledge	265	40.0	48.7	42.5	38.1	40.0	50.2
college_biology	144	40.3	45.1	39.9	38.2	41.3	45.1
college_chemistry	100	31.5	52.0	22.5	41.0	23.5	60.0
college_computer_science	100	30.0	40.0	29.5	47.0	29.5	62.0
college_mathematics	100	24.0	33.0	19.0	38.0	22.0	70.0
college_medicine	173	31.8	41.6	32.4	35.8	29.5	53.8
college_physics	102	16.7	34.3	21.6	43.1	23.0	57.8
computer_security	100	44.5	30.0	47.5	41.0	48.5	47.0
conceptual_physics	235	32.1	31.9	31.5	36.2	33.8	42.1
econometrics	114	28.5	46.5	29.8	49.1	28.1	56.1
electrical_engineering	145	31.0	37.9	30.3	47.6	31.0	57.2
elementary_mathematics	378	24.9	37.0	24.5	34.7	25.0	59.3
formal_logic	126	22.2	40.5	23.0	51.6	21.4	84.9
global_facts	100	31.5	54.0	29.5	24.0	32.0	63.0
high_school_biology	310	45.3	33.9	44.5	42.3	43.5	51.0
high_school_chemistry	203	30.8	41.4	28.6	43.8	30.3	53.2
high_school_computer_science	100	39.0	20.0	40.5	37.0	37.5	47.0
high_school_european_history	165	47.9	45.5	47.6	43.6	44.8	52.7
high_school_geography	198	44.4	37.4	45.5	39.4	41.7	55.6
high_school_government_and_politics	193	54.9	31.6	56.2	32.1	52.8	43.5
high_school_macroeconomics	390	35.6	37.9	35.6	40.8	34.0	47.7
high_school_mathematics	270	18.1	30.7	18.5	25.2	18.7	54.1
high_school_microeconomics	238	40.5	34.9	33.8	46.2	37.0	47.9
high_school_physics	151	30.1	31.8	27.8	41.7	26.8	58.3
high_school_psychology	545	47.2	35.4	46.4	34.3	45.3	46.8
high_school_statistics	216	27.3	34.3	26.2	44.4	26.2	59.3
high_school_us_history	204	54.2	38.2	53.2	41.7	51.5	51.0
high_school_world_history	237	50.4	35.4	50.8	40.9	52.3	48.5
human_aging	223	40.6	39.5	35.4	37.2	41.3	48.4
human_sexuality	131	21.4	19.8	22.9	19.1	23.7	32.8
international_law	121	63.2	29.8	63.6	35.5	64.0	39.7
jurisprudence	108	49.5	38.0	46.8	39.8	47.7	50.9
logical_fallacies	163	44.2	37.4	48.2	44.8	43.6	47.2
machine_learning	112	28.6	26.8	27.2	37.5	30.4	38.4
management	103	42.7	38.8	40.8	39.8	41.7	46.6
marketing	234	53.4	45.3	55.6	36.8	55.3	47.9
medical_genetics	100	35.0	39.0	33.5	42.0	34.5	52.0
miscellaneous	783	49.7	36.0	48.9	31.2	52.8	51.5
moral_disputes	346	37.7	37.0	37.0	41.9	38.0	47.1
moral_scenarios	895	18.4	23.6	18.2	6.8	18.6	80.1
nutrition	306	38.1	45.8	37.9	38.9	40.4	52.3
philosophy	311	45.3	23.5	42.4	39.9	43.2	41.5
prehistory	324	42.4	43.2	42.7	34.0	42.4	49.1
professional_accounting	282	31.7	47.2	31.7	41.8	31.6	54.6
professional_law	1534	30.7	34.5	30.9	43.9	30.1	57.0
professional_medicine	272	31.4	39.3	30.9	40.8	30.0	57.4
professional_psychology	612	38.4	41.3	39.1	37.6	38.4	50.3
public_relations	110	44.5	35.5	44.5	34.5	42.3	47.3
security_studies	245	38.0	39.6	38.2	43.3	37.6	51.0
sociology	201	49.0	34.8	50.0	35.8	49.0	40.3
us_foreign_policy	100	55.5	38.0	48.5	42.0	49.5	41.0
virology	166	37.0	32.5	32.5	37.3	34.9	41.6
world_religions	171	43.0	37.4	50.0	32.7	53.2	43.3

Table 10: Results of the sensitivity experiment across 57 MMLU subtasks for LLaMA 2 13B, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

Subtask	#sample	Token		Order		Both	
		Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate	Avg. Acc	Fluct. Rate
abstract_algebra	100	36.0	41.0	36.5	71.0	33.5	58.0
anatomy	135	41.9	57.0	44.1	65.2	46.7	39.3
astronomy	152	44.7	60.5	53.9	50.7	55.9	40.8
business_ethics	100	45.5	60.0	44.5	48.0	46.5	57.0
clinical_knowledge	265	49.4	57.0	53.8	49.4	54.0	40.0
college_biology	144	50.7	55.6	49.7	53.5	51.7	41.0
college_chemistry	100	30.5	76.0	40.5	76.0	29.5	53.0
college_computer_science	100	38.5	64.0	41.0	57.0	38.0	53.0
college_mathematics	100	31.0	63.0	32.0	68.0	26.5	61.0
college_medicine	173	39.3	50.9	42.2	46.8	40.2	50.3
college_physics	102	25.5	67.6	32.4	76.5	24.5	55.9
computer_security	100	58.5	36.0	53.0	48.0	55.0	35.0
conceptual_physics	235	40.4	46.4	40.4	50.2	39.8	45.1
econometrics	114	30.3	77.2	28.9	51.8	32.9	67.5
electrical_engineering	145	39.3	62.8	43.8	57.2	40.3	48.3
elementary_mathematics	378	31.7	72.0	32.8	77.0	32.4	55.0
formal_logic	126	23.8	53.2	28.2	65.9	22.6	50.8
global_facts	100	30.0	77.0	26.0	86.0	30.0	59.0
high_school_biology	310	54.7	49.0	58.4	41.0	56.9	44.2
high_school_chemistry	203	31.0	77.8	36.7	71.9	36.5	46.3
high_school_computer_science	100	50.0	58.0	45.0	52.0	52.0	49.0
high_school_european_history	165	60.0	40.6	58.5	25.5	55.2	49.1
high_school_geography	198	56.1	53.5	62.6	36.4	60.9	39.9
high_school_government_and_politics	193	64.5	38.3	66.6	35.2	68.9	26.9
high_school_macroeconomics	390	45.0	57.2	49.9	57.2	49.1	40.5
high_school_mathematics	270	27.0	76.3	31.3	71.9	28.3	65.9
high_school_microeconomics	238	45.0	62.6	50.8	60.1	50.4	40.3
high_school_physics	151	30.8	66.9	33.4	69.5	29.8	52.3
high_school_psychology	545	62.1	45.3	66.5	32.5	66.1	35.2
high_school_statistics	216	30.8	65.7	42.6	64.4	34.0	41.2
high_school_us_history	204	58.8	47.5	62.7	31.9	61.3	45.6
high_school_world_history	237	62.7	41.4	62.0	32.9	64.1	38.0
human_aging	223	50.9	59.2	41.9	53.8	50.2	45.3
human_sexuality	131	33.6	30.5	33.6	19.8	34.7	32.8
international_law	121	64.5	46.3	62.8	44.6	68.2	33.1
jurisprudence	108	56.0	47.2	56.9	40.7	60.2	36.1
logical_fallacies	163	54.0	49.7	54.6	39.9	58.9	39.3
machine_learning	112	34.4	43.8	30.4	44.6	36.2	30.4
management	103	52.4	49.5	61.7	33.0	58.3	44.7
marketing	234	68.4	43.6	64.3	31.6	71.8	35.0
medical_genetics	100	49.0	62.0	47.0	56.0	49.5	45.0
miscellaneous	783	67.6	37.0	66.5	35.1	70.6	31.5
moral_disputes	346	48.1	63.3	47.8	52.6	51.9	34.4
moral_scenarios	895	26.1	34.1	23.9	24.5	22.5	46.9
nutrition	306	46.4	58.2	47.7	51.6	49.7	39.9
philosophy	311	51.9	59.2	55.0	49.8	58.8	34.7
prehistory	324	51.7	58.0	52.5	51.9	59.6	37.0
professional_accounting	282	32.3	71.6	32.6	69.5	37.1	46.5
professional_law	1534	33.6	53.8	34.0	50.3	36.0	47.3
professional_medicine	272	28.3	54.4	38.6	41.9	33.5	61.4
professional_psychology	612	47.0	56.7	44.1	53.1	50.4	39.1
public_relations	110	50.9	47.3	48.2	48.2	50.9	44.5
security_studies	245	43.7	72.7	50.4	50.6	47.8	44.1
sociology	201	61.4	48.8	63.2	40.8	65.7	31.8
us_foreign_policy	100	69.0	36.0	68.0	38.0	70.0	36.0
virology	166	38.9	60.2	40.4	39.2	39.5	40.4
world_religions	171	66.7	37.4	64.9	33.9	69.0	23.4

Table 11: Results of the sensitivity experiment across 57 MMLU subtasks for LLaMA 2 70B, including different sensitivity settings: *Token*, *Order*, and *Both*. **Avg. Acc** represents the mean of $r_{forward}$ and $r_{backward}$ accuracies for each setting.

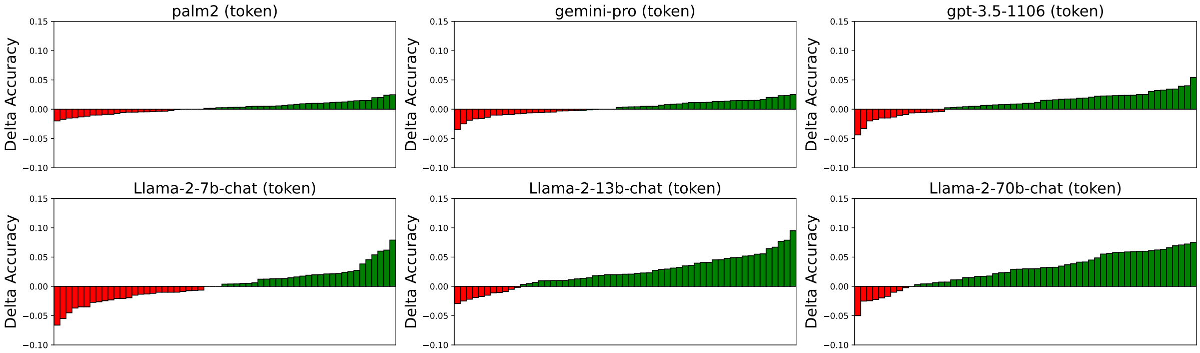

Figure 6: Accuracy Difference Distribution Across 57 MMLU Subtasks in the Black-Box Scenario With Token Sensitivity Setting: Subtasks are sorted by the difference in accuracy from low to high, indicating that subtasks towards the right benefit more from our methodology. Improvements are marked in green, whereas declines in performance are highlighted in red.

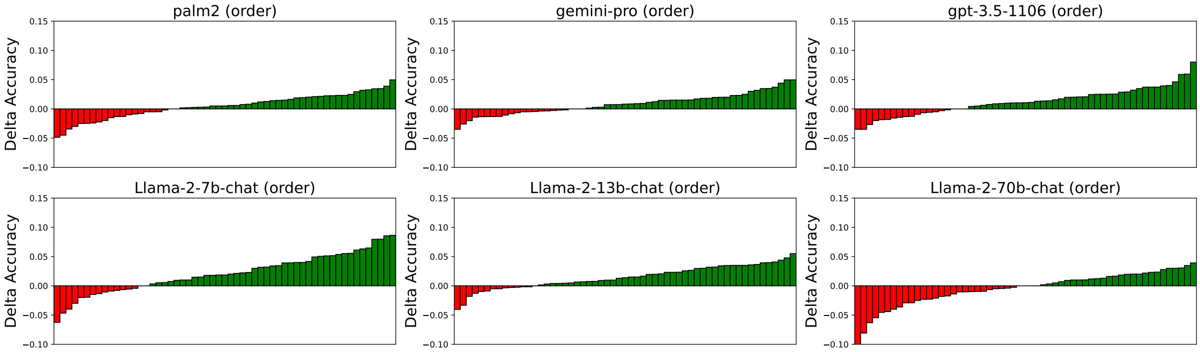

Figure 7: Accuracy Difference Distribution Across 57 MMLU Subtasks in the Black-Box Scenario With Order Sensitivity Setting: Subtasks are sorted by the difference in accuracy from low to high, indicating that subtasks towards the right benefit more from our methodology. Improvements are marked in green, whereas declines in performance are highlighted in red.

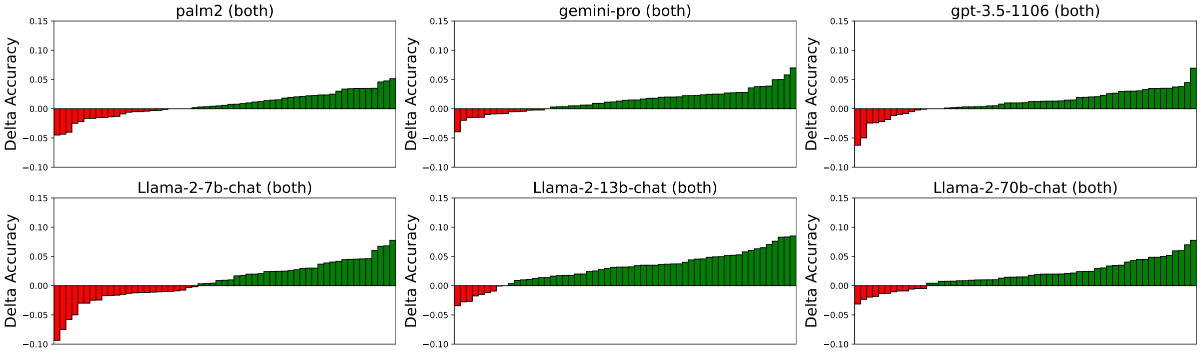

Figure 8: Accuracy Difference Distribution Across 57 MMLU Subtasks in the Black-Box Scenario: Subtasks are sorted by the difference in accuracy from low to high, indicating that subtasks towards the right benefit more from our methodology. Improvements are marked in green, whereas declines in performance are highlighted in red.

	A (%)	B (%)	C (%)	D (%)
Ground truth	25.04	24.75	**25.73**	24.48
PaLM 2	23.47	24.54	**26.26**	25.73
Gemini Pro	15.94	27.96	**30.17**	25.92
GPT 3.5	18.98	**32.70**	27.13	21.19
LLaMA2-7B	0.05	**55.56**	27.16	17.23
LLaMA2-13B	1.17	**65.41**	28.82	4.60
LLaMA2-70B	11.36	**38.78**	33.93	15.93

Table 12: Option proportion statistics and ground truth label proportions for the HellaSwag dataset. The most frequent option in each row is highlighted in **bold**.

	A (%)	B (%)	C (%)	D (%)
Ground truth	22.95	24.65	25.51	**26.88**
PaLM 2	15.32	**29.30**	29.17	26.20
Gemini Pro	13.74	26.85	28.79	**30.62**
GPT 3.5	21.32	**30.55**	27.51	20.62
LLaMA2-7B	**47.82**	26.34	22.65	3.20
LLaMA2-13B	10.66	**43.65**	34.85	10.84
LLaMA2-70B	11.30	35.93	**36.60**	16.17

Table 13: Option proportion statistics and ground truth label proportions for the MMLU dataset. The most frequent option in each row is highlighted in **bold**.

	A (%)	B (%)	C (%)	D (%)
Ground truth	**27.60**	25.20	26.40	20.80
PaLM 2	24.30	**26.71**	26.31	22.69
Gemini Pro	22.60	26.00	**29.80**	21.60
GPT 3.5	19.88	31.73	**29.92**	18.47
LLaMA2-7B	**69.15**	14.11	16.73	0.00
LLaMA2-13B	1.04	35.07	**53.65**	10.23
LLaMA2-70B	8.01	31.21	**39.84**	20.94

Table 14: Option proportion statistics and ground truth label proportions for the OpenBookQA dataset. The most frequent option in each row is highlighted in **bold**.

	A (%)	B (%)
Ground truth	49.57	**50.43**
PaLM 2	30.59	**69.41**
Gemini Pro	19.02	**80.98**
GPT 3.5	41.48	**58.52**
LLaMA2-7B	0.08	**99.92**
LLaMA2-13B	0.53	**99.47**
LLaMA2-70B	**100.00**	0.00

Table 15: Option proportion statistics and ground truth label proportions for the Winogrande dataset. The most frequent option in each row is highlighted in **bold**.

	A (%)	B (%)	C (%)	D (%)	E (%)
Ground truth	20.80	20.27	**22.58**	20.94	15.41
PaLM 2	0.67	18.50	**37.56**	27.19	16.08
Gemini Pro	1.21	20.74	**30.59**	24.46	23.02
GPT 3.5	1.99	22.90	**45.73**	25.33	4.05
LLaMA2-7B	**38.21**	24.51	32.32	4.96	0.00
LLaMA2-13B	0.27	**57.29**	37.61	3.65	1.18
LLaMA2-70B	0.24	14.10	**74.52**	7.05	4.08

Table 16: Option proportion statistics and ground truth label proportions for the MathQA dataset. The most frequent option in each row is highlighted in **bold**.

		Token		Order		Both	
Subtask	**Subcategory**	**Acc**	**Diff**	**Acc**	**Diff**	**Acc**	**Diff**
abstract_algebra	STEM	27.00	1.50	37.00	4.50	39.00	8.00
us_foreign_policy	Social Sciences	83.00	0.50	84.00	3.00	88.00	7.50
college_chemistry	STEM	43.00	2.50	47.00	0.50	50.00	7.00
elementary_mathematics	STEM	29.89	4.37	30.69	7.67	32.01	6.48
computer_security	STEM	73.00	2.50	76.00	7.00	80.00	6.00
high_school_computer_science	STEM	66.00	6.00	65.00	2.50	70.00	6.00
global_facts	Other	41.00	3.00	35.00	0.50	39.00	5.00
moral_disputes	Humanities	68.79	3.03	68.79	3.18	69.36	4.62
astronomy	STEM	75.00	3.29	75.00	5.92	74.34	4.28
high_school_european_history	Humanities	72.84	1.02	76.54	5.94	77.16	4.13
professional_psychology	Social Sciences	65.85	2.53	66.01	2.45	68.30	4.08
prehistory	Humanities	68.52	1.54	74.07	4.94	72.22	4.01
medical_genetics	Other	72.00	3.50	75.00	6.00	77.00	4.00
formal_logic	Humanities	38.10	0.79	37.30	2.78	40.48	3.97
econometrics	Social Sciences	38.60	0.88	40.35	3.07	41.23	3.95
management	Other	78.64	2.43	78.64	2.43	81.55	3.88
high_school_biology	STEM	77.42	2.58	77.42	3.55	78.39	3.71
jurisprudence	Humanities	75.93	1.85	76.85	2.78	76.85	3.70
security_studies	Social Sciences	65.71	1.63	66.53	-0.20	67.35	3.67
philosophy	Humanities	71.38	5.47	71.38	4.34	71.38	3.54
high_school_us_history	Humanities	79.90	2.21	81.86	3.92	81.86	3.43
nutrition	Other	69.28	2.12	72.22	3.76	72.22	3.27
high_school_chemistry	STEM	50.25	2.71	50.25	3.45	53.69	3.20
conceptual_physics	STEM	57.87	3.19	55.32	2.98	57.02	3.19
high_school_statistics	STEM	45.83	2.55	47.22	4.86	46.76	3.01
high_school_world_history	Humanities	79.32	0.84	79.75	2.11	82.28	2.95
college_physics	STEM	34.31	4.90	38.24	2.45	37.25	2.94
human_aging	Other	67.71	0.00	68.61	1.79	70.40	2.69
high_school_mathematics	STEM	18.52	2.22	21.11	5.00	18.52	2.41
high_school_macroeconomics	Social Sciences	58.46	0.38	60.00	3.33	60.26	2.31
high_school_microeconomics	Social Sciences	68.07	2.73	67.23	1.26	68.49	2.10
international_law	Humanities	73.55	0.41	76.03	1.24	76.86	2.07
moral_scenarios	Humanities	23.24	1.62	17.99	-3.46	23.91	1.96
professional_law	Humanities	46.94	1.66	47.00	1.92	47.98	1.86
public_relations	Social Sciences	65.45	1.36	65.45	3.64	67.27	1.82
miscellaneous	Other	86.59	2.87	87.10	2.17	87.99	1.79
high_school_geography	Social Sciences	81.31	2.27	80.30	2.53	79.80	1.77
college_medicine	Other	58.38	2.31	58.96	3.47	59.54	1.73
high_school_physics	STEM	34.44	4.64	29.80	4.64	31.79	1.66
human_sexuality	Social Sciences	76.34	3.44	75.57	2.29	75.57	1.53
college_computer_science	STEM	55.00	5.50	51.00	6.00	49.00	1.50
marketing	Other	88.03	2.78	88.46	2.35	89.74	1.50
professional_medicine	Other	68.01	2.76	70.59	5.15	70.96	1.29
anatomy	STEM	66.67	3.70	67.41	4.81	65.19	1.11
college_biology	STEM	72.22	2.43	72.92	-0.00	72.92	1.04
electrical_engineering	STEM	58.62	2.07	57.24	-0.34	56.55	1.03
sociology	Social Sciences	81.59	1.24	82.59	3.23	80.10	1.00
clinical_knowledge	Other	68.30	1.32	69.43	2.08	70.57	0.94
high_school_psychology	Social Sciences	84.40	2.29	85.87	4.31	84.22	0.64
professional_accounting	Other	44.68	2.13	47.16	2.66	45.39	0.53
high_school_government_and_politics	Social Sciences	87.56	0.78	87.05	1.55	88.08	0.52
business_ethics	Other	61.00	3.50	61.00	-3.00	63.00	0.50
college_mathematics	STEM	27.00	0.00	35.00	4.00	28.00	0.50
logical_fallacies	Humanities	69.94	1.84	68.10	0.92	71.17	0.00
world_religions	Humanities	82.46	2.92	83.63	2.92	82.46	-1.17
virology	Other	48.80	-0.60	48.80	-1.20	46.39	-2.41
machine_learning	STEM	44.64	2.23	45.54	0.89	45.54	-3.57

Table 17: Results of probability weighting method of GPT-3.5 model across 57 MMLU subtask.

		Token		**Order**		**Both**	
Subtask	**Subcategory**	**Acc**	**Diff**	**Acc**	**Diff**	**Acc**	**Diff**
elementary_mathematics	STEM	39.42	13.89	36.51	13.49	39.81	14.29
high_school_mathematics	STEM	28.89	12.59	26.67	10.56	28.33	12.22
college_physics	STEM	41.18	11.76	43.63	7.84	45.59	11.27
college_chemistry	STEM	44.00	3.50	49.00	2.50	50.00	7.00
formal_logic	Humanities	41.67	4.37	38.49	3.97	40.08	3.57
college_computer_science	STEM	51.50	2.00	47.00	2.00	51.00	3.50
high_school_statistics	STEM	47.92	4.63	44.68	2.31	46.99	3.24
college_mathematics	STEM	28.50	1.50	31.50	0.50	29.50	2.00
global_facts	Other	40.50	2.50	34.00	-0.50	36.00	2.00
abstract_algebra	STEM	29.00	3.50	33.00	0.50	33.00	2.00
high_school_physics	STEM	31.46	1.66	29.14	3.97	32.12	1.99
econometrics	Social Sciences	37.72	0.00	37.72	0.44	39.04	1.75
high_school_chemistry	STEM	50.00	2.46	49.26	2.46	52.22	1.72
computer_security	STEM	71.00	0.50	70.50	1.50	75.50	1.50
professional_accounting	Other	44.50	1.95	45.39	0.89	46.28	1.42
college_medicine	Other	56.94	0.87	56.65	1.16	58.96	1.16
anatomy	STEM	64.07	1.11	64.07	1.48	65.19	1.11
high_school_microeconomics	Social Sciences	65.55	0.21	66.81	0.84	67.44	1.05
medical_genetics	Other	70.50	2.00	72.00	3.00	74.00	1.00
astronomy	STEM	72.04	0.33	70.07	0.99	71.05	0.99
nutrition	Other	67.81	0.65	70.10	1.63	69.93	0.98
high_school_biology	STEM	75.48	0.65	75.00	1.13	75.65	0.97
security_studies	Social Sciences	64.49	0.41	67.55	0.82	64.49	0.82
clinical_knowledge	Other	68.11	1.13	68.30	0.94	70.38	0.75
high_school_us_history	Humanities	77.70	0.00	78.43	0.49	79.17	0.74
high_school_psychology	Social Sciences	82.39	0.28	82.11	0.55	84.31	0.73
philosophy	Humanities	66.24	0.32	67.04	0.00	68.49	0.64
high_school_macroeconomics	Social Sciences	59.36	1.28	57.31	0.64	58.59	0.64
conceptual_physics	STEM	55.11	0.43	52.77	0.43	54.47	0.64
professional_medicine	Other	65.62	0.37	65.99	0.55	70.22	0.55
high_school_geography	Social Sciences	79.55	0.51	77.78	0.00	78.54	0.51
high_school_computer_science	STEM	61.50	1.50	63.50	1.00	64.50	0.50
professional_law	Humanities	45.31	0.03	45.24	0.16	46.61	0.49
prehistory	Humanities	66.67	-0.31	68.21	-0.93	68.67	0.46
high_school_european_history	Humanities	72.22	0.40	71.60	1.00	73.46	0.43
college_biology	STEM	70.49	0.69	72.57	-0.35	72.22	0.35
virology	Other	49.10	-0.30	49.70	-0.30	49.10	0.30
world_religions	Humanities	79.24	-0.29	81.58	0.88	83.92	0.29
marketing	Other	85.26	0.00	86.11	0.00	88.46	0.21
miscellaneous	Other	84.29	0.57	85.19	0.26	86.40	0.19
moral_scenarios	Humanities	21.62	0.00	21.34	-0.11	22.12	0.17
international_law	Humanities	73.55	0.41	75.21	0.41	74.79	0.00
human_sexuality	Social Sciences	73.28	0.38	72.52	-0.76	74.05	0.00
logical_fallacies	Humanities	67.79	-0.31	66.87	-0.31	71.17	0.00
electrical_engineering	STEM	55.86	-0.69	57.24	-0.34	55.52	0.00
business_ethics	Other	57.00	-0.50	63.50	-0.50	62.50	0.00
management	Other	76.70	0.49	75.73	-0.49	77.67	0.00
high_school_government_and_politics	Social Sciences	86.53	-0.26	85.49	0.00	87.56	0.00
professional_psychology	Social Sciences	63.24	-0.08	63.89	0.33	64.05	-0.16
high_school_world_history	Humanities	78.06	-0.42	77.64	-0.00	79.11	-0.21
sociology	Social Sciences	80.60	0.25	79.60	0.25	78.86	-0.25
human_aging	Other	67.26	-0.45	66.59	-0.22	67.26	-0.45
us_foreign_policy	Social Sciences	82.50	0.00	80.50	-0.50	80.00	-0.50
machine_learning	STEM	44.20	-0.89	44.20	-0.45	48.21	-0.89
public_relations	Social Sciences	62.73	-1.36	60.00	-1.82	64.55	-0.91
jurisprudence	Humanities	74.54	0.46	73.61	-0.46	72.22	-0.93
moral_disputes	Humanities	65.61	-0.14	65.03	-0.58	63.73	-1.01

Table 18: Results of probability calibration method of GPT-3.5 model across 57 MMLU subtask.