PRIME: Large Language Model Personalization with Cognitive Dual-Memory and Personalized Thought Process

Xinliang Frederick Zhang[1], Nick Beauchamp[2], and Lu Wang[1]

[1]University of Michigan,
[2]Northeastern University

Personalization

Preamble: Personalization (Schafer et al., 2001; Berkovsky et al., 2005) aims to align model outputs with individuals' unique needs, preferences and opinions.

Background:

- Early efforts include building Explicit User Models, utilizing Latent-factor Techniques, and leveraging Learnable User Embedding.
- Nowadays, users' demand for personalized LLMs that reflect their unique histories and preferences has grown (Salemi et al., 2024; Liu et al., 2025).
- Personalization adopted into various commercial applications.

Literature Review: Three major paradigms have emerged for realizing LLM personalization.

- Prompt Engineering
- Retrieval-augmented Generation
- Training-based parameterization

Limitations (Methods): In the community, there lacks a unified framework for systematically identifying which approach makes personalization more effective.

Limitations (Data): Existing benchmarks mainly focus on short-context queries and surface-level imitation.

Data: CMV Corpus

- To embark on genuine personalization, capturing users' latent beliefs and perspectives, we introduce CMV (Change My View) corpus.
- CMV corpus is derived from CMV reddit forum, where participants engage in extended dialogues, seeking to change original posters' opinions.
- **Statistics:** CMV evaluation set includes 133 queries by 41 OP authors, supported by 7,514 historical conversations published from 2013 to 2022. In the historical engagement set, active authors have on average 28.1 positive and 155.1 negative conversations each.
- **Challenges:** LLMs expected to understand nuanced user beliefs and preferences in long-context setting.

The author, `kingpatzer`, has engaged with users on the Change-My-View subreddit across various original posts (OPs) and is seeking alternative opinions to alter their viewpoint.
Currently, the author is creating a new OP titled

> "CMV: Those who attribute gun ownership rates as the cause of the problem of gun violence in terms of criminal gun deaths are not merely mistaken; they are disingenuous"

with the following content:

> The data has been clear for a very long time: the relationship between guns and gun homicides doesn't show any strong correlation.
>
> I have personally taken the cause-of-death data from https://wonder.cdc.gov/, grouping results by year and state, and selecting *Homicide, Firearm* as the cause of death. I then matched that data to the per-capita gun-ownership statistics by state from the ATF, as reported by Hunting Mark (https://huntingmark.com/gun-ownership-stats/).
>
> A standard correlation analysis between firearm homicide rates per 100,000 and per-capita gun ownership yields an r^2 of 0.079 (no meaningful correlation). A similar global analysis by nation gives an r^2 of 0.02…
>
> The only way to associate gun ownership with gun violence is by including suicides by firearm, which I argue is disingenuous. We don't count suicide by hanging as "rope violence" when discussing strangulation, nor overdoses as "drug violence," etc.

From the `candidate replies` JSON file below, select the top 3 replies (using `option ID`) that best challenge the author's view. Rank them from most to least compelling.

```
[
  { 'option ID': '...', 'challenger': '...', 'reply': '...' },
  { 'option ID': '...', 'challenger': '...', 'reply': '...' },
]
```

Figure 1: A sample evaluation query from our CMV dataset, and a sample candidate reply (→).

Positive Candidate Reply (option F):

- **Option ID:** `option F`
- **Challenger:** `An-Okay-Alternative`
- **Reply:**

  Your data for gun ownership is weapons per capita, not individual gun owners per capita. If we're testing access to guns vs. gun homicides, someone who owns 30 guns wouldn't be 30x as likely to commit a homicide.

  Secondly, the ATF list includes only specially regulated firearms (e.g. fully automatic weapons, short-barreled shotguns) and NFA items bought by law enforcement.

  Thus, the data omits common firearms, is biased by collectors and hobbyists, and is confounded by law-enforcement purchases.

  Overall, this calculation is weak evidence against a gun-homicide correlation and doesn't imply critics are dishonest.

PRIME (Framework) & Personalized Thinking

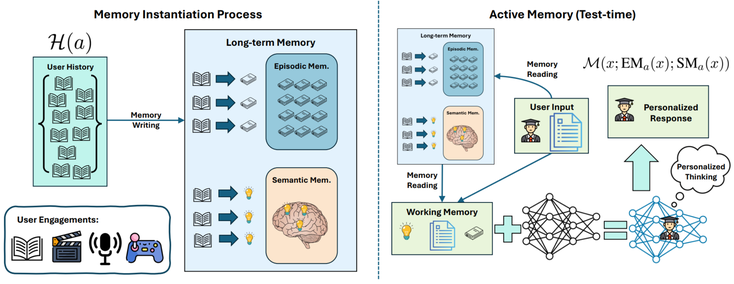

Figure 2: Overview of our unified framework, PRIME, augmented with personalized thinking.

General Formulation:

$$\tilde{\mathcal{M}}(x) = \mathcal{M}(x; \mathrm{EM}_a(x); \mathrm{SM}_a(x)) = \mathcal{M}(x; \phi(x, \mathcal{H}(a)); \theta \oplus \Delta_{\mathcal{H}(a)})$$

Episodic Memory (EM):

- Recall Complete History
- Recall Recent History
- Recall Relevant History

Semantic Memory (SM):

Parametric form:

- Input-Only Training (i.e., no target)
- Fine-Tuning (FT)
- Preference Tuning

Textual form:

- Hierarchical Summarization
- Parametric Knowledge Reification

Realizing personalized thinking via self-distillation (more details in paper):

- Profile Generation
- Review History Engagement
- Fast-thinking Filtering
- Proxy LLM Initialization & Reasoning
- Slow-thinking Filtering

Personalized Thinking Trace

User Experience: The author, `kingpatzer`, has engaged with users on the Change-My-View subreddit across various original posts (OPs), seeking alternative opinions to alter their viewpoint. In past discussions, they've shown openness to different perspectives and a willingness to consider data and evidence about gun ownership and gun violence. However, they can become defensive when challenged and sometimes dismiss opposing viewpoints.

OP Summary: The author is creating a new OP titled

> CMV: Those who attribute gun ownership rates as the cause of the problem of gun violence in terms of criminal gun deaths are not merely mistaken; they are disingenuous

They argue that available data show no strong correlation between gun ownership rates and gun homicides, and that including firearm suicides is disingenuous—comparing it to "rope violence" or "drug violence" when discussing strangulation or overdoses.

Sketch Outline:
To challenge the author's view, we need to address the following points:
1. The author's interpretation of the data: We need to examine the author's methodology and data analysis to see if it is sound and if it supports their conclusion. 2. The inclusion of suicide by guns: We need to discuss the relevance of including suicide by guns in the data set and why it is not disingenuous to do so. 3. The comparison to other causes of death: We need to compare the author's approach to other causes of death, such as drug overdoses, to see if it is consistent and fair. 4. The author's tone and language: We need to address the author's tone and language, which some may perceive as dismissive and condescending.
Key questions to ask:
* What is the author's definition of "disingenuous" and how does it apply to including suicide by guns in the data set?
* Is the author's methodology sound and does it support their conclusion? * How does the author's approach to gun ownership and gun violence compare to other causes of death? * Why is the author using a tone and language that some may perceive as dismissive and condescending?

Analysis (option F):
This reply challenges the author's view by pointing out that the data used to support their conclusion is flawed, and that the author's methodology is not sound. The reply also highlights the importance of considering the social and cultural context in which gun ownership and gun violence occur.

Reflection:
Based on the analysis, the top 3 replies that best challenge the author's view are:
1. Option F: This reply challenges the author's view by pointing out that the data used to support their conclusion is flawed, and that the author's methodology is not sound. The reply also highlights the importance of considering the social and cultural context in which gun ownership and gun violence occur. 2. Option D: This reply challenges the author's view by pointing out that there is a strong link between gun ownership and impulsive suicide, and that including suicide by guns in the data set is not disingenuous. The reply also highlights the importance of considering the cultural context in which gun ownership and gun violence occur. 3. Option C: This reply challenges the author's view by providing a well-researched argument that challenges the author's view, pointing out that there is a significant correlation between gun ownership and gun violence. The reply also highlights the importance of considering the social and cultural context in which gun ownership and gun violence occur.
These replies are the most compelling because they engage with the author's perspective, provide reasoned and respectful arguments, and challenge the author's view in a thoughtful and nuanced way.

Answer:

`["option F", "option D", "option C"]`

Figure 3: Personalized thinking trace generated by PRIME.

Results & Analyses

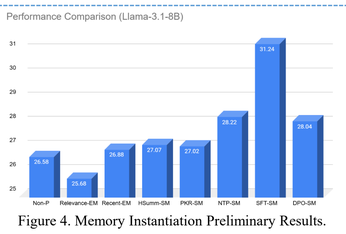

Figure 4. Memory Instantiation Preliminary Results.

- Episodic memory grounded in simple recency often outperforms a semantic-similarity retrieval strategy.
- PKR-produced summaries are of equal qualities as Hierarchical Summarization, but more efficient.
- Overall, using SM alone leads to better results compared to using EM alone. Specifically, EM < Textual SM < Parametric SM.
- Surprisingly, DPO underperforms, likely due to data pairing issue (1 positive paired with 10 negatives).

	Non-P		EM		SM		DUAL		PRIME	
	Hit@3	Avg	Hit@3	Avg	Hit@3	Avg	Hit@3	Avg	Hit@3	Avg
Llama-3.2-3B	38.65	26.44	37.89	26.27	**43.61**	**30.25**	41.95	28.87	42.93	29.95
Llama-3.1-8B	36.77	26.58	37.22	26.88	43.01	31.24	44.59	32.24	**45.79**	**34.13**
Ministral-8B	36.77	25.60	38.27	26.67	**40.83**	27.97	**40.83**	28.39	40.75	**28.99**
Qwen2.5-7B	39.10	27.89	37.47	25.51	43.38	30.20	41.58	28.71	**45.19**	**32.29**
Qwen2.5-14B	41.28	30.24	43.01	30.65	51.35	37.22	52.03	37.68	**52.03**	**38.15**
Phi-4	41.50	29.63	42.93	30.31	42.63	31.09	43.98	32.61	**47.29**	**35.15**

Table 1. Comprehensive results on CMV evaluation set (average of 10 runs).

- Generic reasoning has limitations
- Semantic memory (SM) beats episodic memory (EM)
- DUAL often underperforms SM alone
- Model-agnostic effectiveness of PRIME
- Personalized thinking is crucial

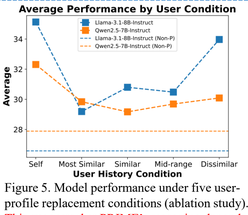

Figure 5. Model performance under five user-profile replacement conditions (ablation study). This suggests that PRIME's reasoning depends critically on correct user history, and cannot be explained by bandwagon or popularity heuristics.

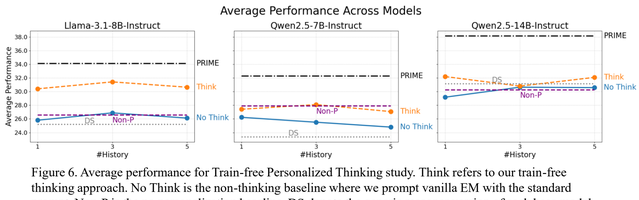

Figure 6. Average performance for Train-free Personalized Thinking study. Think refers to our train-free thinking approach. No Think is the non-thinking baseline where we prompt vanilla EM with the standard prompt. Non-P is the no personalization baseline. DS denote the generic reasoner version of each base model. Our train-free approach outperforms all non-PRIME baselines including the strong generic reasoner (i.e., R1-distill LLMs). This offers an effective way to handle "cold-start" challenge.

Code: github.com/launchnlp/LM_Personalization

Contact: xlfzhang@umich.edu

Paper

Codebase & Data

EMNLP 2025