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# Technical Report: Competition Solution For 2025 BEHAVIOR Challenge

Team Comet



[https://huggingface.co/sunshk/comet\\_submission](https://huggingface.co/sunshk/comet_submission)



<https://github.com/mli0603/openpi-comet>

## Abstract

The 2025 BEHAVIOR Challenge is presented to rigorously track progress toward generalizable physical agents in simulation environment. BEHAVIOR-1K focuses on everyday household tasks that people most want robots to assist with and these tasks introduce long-horizon mobile manipulation challenges in realistic settings, bridging the gap between current research and real-world, human-centric applications. This report presents our solution to the 2025 BEHAVIOR Challenge in a very close 2nd place and substantially outperforms the rest of the submissions. Building on  $\pi_{0.5}$ , we focus on systematically building our solution by studying the effects of training techniques and data. Through careful ablations, we show the scaling power in pre-training and post-training phases for competitive performance. We summarize our practical lessons and design recommendations that we hope will provide actionable insights for the broader embodied AI community when adapting powerful foundation models to complex embodied scenarios.

## 1 Introduction

Vision-Language-Action (VLA) models (Brohan et al., 2022; 2023; Octo Model Team et al., 2024; Kim et al., 2024; Qu et al., 2025; Black et al., 2024) have recently emerged as a unifying paradigm for robotic policy learning, leveraging large-scale robot datasets to acquire robust and generalizable manipulation and navigation capabilities. By integrating perception, language understanding, and control within a single end-to-end framework, VLAs bypass the need for hand-engineered modules and have demonstrated strong performance across a variety of embodied AI benchmarks. Despite this progress, most existing VLA systems are primarily optimized for short-horizon tasks, and their ability to scale to complex, temporally extended activities remains limited.

Long-horizon manipulation (Zhao et al., 2025; Zawalski et al., 2024) introduces additional difficulties that fundamentally challenge current VLA designs. Such tasks require orchestrated sequences of interdependent behaviors, where compounding errors and shifting state distributions can degrade performance over time. A common approach is to decompose tasks into subtasks (Lin et al., 2022; Shi et al., 2023; Tie et al., 2025) and train separate local policies. However, this strategy does not resolve the skill chaining problem (Chen et al., 2024; Konidaris & Barto, 2009), which involves modeling and executing reliable transitions between subtasks while mitigating error accumulation. In addition, many solutions proposed for skill chaining rely on online adaptation or modular architectures, and these methods are often incompatible with the large-scale, offline, end-to-end training paradigm that underpins modern VLA models. Consequently, achieving reliable long-horizon performance while preserving scalability and generality remains an open challenge.

The BEHAVIOR Challenge, built upon the BEHAVIOR-1K (Li et al., 2024) benchmark, provides an rigorous benchmark for this problem. It features realistic household environments containing complex object interactions, and evaluates agents on 50 long-horizon tasks that reflect human-centered daily activities. Each task requires multi-step reasoning, precise manipulation, and coordinated navigation, making success highly dependent on robust long-horizon policy execution. With 10,000 expert demonstrations and a standardized evaluation protocol, the challenge places strong emphasis on generalization, control robustness, and error tolerance. These capabilities remain difficult for current VLA models to achieve consistently.

In this report, we examine how far a strong publicly available VLA backbone can be pushed on long-horizon tasks using careful data, training, and inference design within a simple end-to-end training pipeline. We treat the BEHAVIOR Challenge as a case study in adapting powerful but generic foundation policies to a complex embodied benchmark. Through systematic exploration of training configurations, pre-training choices, and inference strategies, we show that our solution completes 22 tasks out of the 50 household tasks, achieving a Q-score of 0.2514 in the competition [Table 1](#).

Table 1: Results of 2025 BEHAVIOR Challenge for standard track. Q-score for the test set (**bold**) is used for final ranking.

Rank	Team	Full Task Success Rate		Q-Score	
		Validation	Test	Validation	Test
1	Robot Learning Collective	0.1120	0.1240	0.2605	<b>0.2599</b>
2	Comet (ours)	<b>0.1440</b>	<b>0.1140</b>	<b>0.1830<sup>1</sup></b>	<b>0.2514</b>
3	SimpleAI Robot	0.1400	0.1080	0.1943	<b>0.1591</b>
4	The North Star	0.1280	0.0760	0.1702	<b>0.1204</b>

## 2 Architecture

We adopt the  $\pi_{0.5}$  as the base policy of our system.  $\pi_{0.5}$  follows the standard VLA design paradigm, combining a visual encoder for multi-view robot observations with a language encoder for task instructions, and fusing these modalities into a shared representation that conditions a action expert. The action expert is implemented as a transformer-style network that ingests features and denoises the low-level continuous control actions at each timestep. This end-to-end architecture allows perception, language understanding, and control to be trained jointly from large-scale robot datasets, and  $\pi_{0.5}$  further enhances generalization by being pretrained on heterogeneous data spanning multiple embodiments, environments, and tasks.

## 3 Dataset

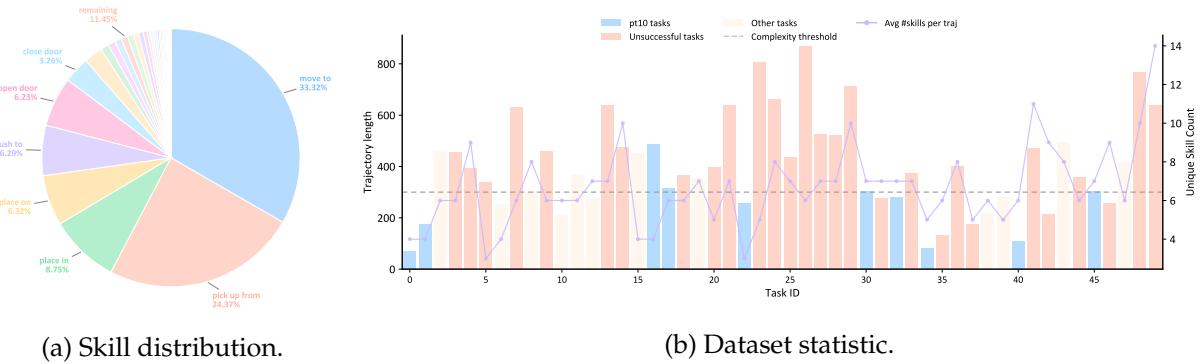


Figure 1: Dataset statistics and skill distribution for BEHAVIOR Challenge @ NeurIPS 2025. (a) Proportion of video frames occupied by each skill across the entire dataset. (b) Per-task distribution, showing the average trajectory length (in frames) and the average number of unique skills per trajectory.

The BEHAVIOR-1K benchmark provides 1,000 realistic household activities instantiated in 50 fully interactive 3D scenes with over 10k objects, designed to stress long-horizon mobile manipulation and high-level reasoning in human-centric environments. The NeurIPS 2025 BEHAVIOR Challenge selects 50 representative tasks from BEHAVIOR-1K and supplies 10,000 teleoperated expert demonstrations (200 per task, over 1,200 hours) with multi-modal observations and fine-grained skill annotations. Policies are evaluated in simulation by the task success rate defined via BDLL goal predicates, emphasizing completion of entire activities rather than short-horizon subroutines.

To better understand the learning landscape, we analyze the official demonstration dataset at the level of semantic skills and per-task complexity. As shown in Figure 1(a), the distribution is highly imbalanced: move to and pick up from dominate with roughly 33.3% and 24.4% of all frames, followed by place in (8.8%) and a long tail of infrequent skills (11.5%). Figure 1(b) further reports per-task statistics: many tasks require trajectories of several hundred frames and typically involve 5–10 distinct skills, with some tasks exceeding 12. We treat tasks with an average length below 250 frames as relatively simple, since they typically involve shorter horizons and fewer skill compositions. These tasks are particularly useful for quickly bringing up our system and validating basic policy behavior in the simulator. In contrast, several tasks including Task 48 and Task 49 fall into a clearly harder regime, characterized by long-horizon execution and rich mixtures of navigation and manipulation skills (e.g., repeatedly moving between rooms, opening/closing containers, and rearranging multiple objects). These high-complexity tasks

<sup>1</sup>Due to limited time by the submission deadline, we could not finish evaluation across all tasks on time. Thus, our submitted validation Q-score is lower than the true validation Q-score reported in Table 2.

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provide a stringent testbed for evaluating policies’ ability to handle extended temporal credit assignment and frequent skill switching.

## 4 Experiment

In this section, we present details of our training setup, from pre-training (Section 4.1) to post-training (Section 4.2). We report the results across different stages in Table 2 and present detailed ablations in Section 4.3.

### 4.1 Pre-training

In order to understand how task coverage and diversity in pre-training affect long-horizon performance, we consider single-task finetuning pt1 and three multi-task pre-training on the BEHAVIOR Challenge, denoted pt7, pt10 and pt50. Each pre-training setting corresponds to training a single VLA policy on demonstrations from a different subset of BEHAVIOR tasks: 7, 10 and the full set of 50 challenge tasks respectively. For each configuration, we train the model end-to-end on the corresponding task subset and then evaluate on the same 50-task challenge protocol. This design allows us to isolate how increasing the number and heterogeneity of pre-training tasks influences task success, while keeping the overall training recipe fixed.

Concretely, pt0 trains the policy only on demonstrations from a single target task; this single-task finetuning regime yields the lowest average success and only produces successful rollouts on 2 tasks, indicating that purely task-specific adaptation is insufficient for robust long-horizon control. Building on this baseline, pt7 pre-trains on a small subset of relatively short-horizon BEHAVIOR Challenge tasks such as bringing water, cook hot dogs, and make microwave popcorn, which share similar interactions with common household objects. As the pre-training set expands from pt7 to pt10 and finally pt50, more tasks begin to exhibit successful rollouts, showing that broader task coverage improves the model’s ability to generalize. In particular, pt10 augments pt7 with additional, slightly more complex tasks (e.g., moving boxes to storage, hanging pictures), while pt50 uses demonstrations from all 50 challenge tasks, including rare and highly compositional activities such as rearranging kitchen furniture and setting the fire, thus exposing the policy to the full long-horizon distribution during pre-training.

After pre-training, we reach a validation Q-score of 0.09 on the validation set, as shown in Table 2.

### 4.2 Post-training

Despite the recent progress in online RL (Chen et al., 2025), its low sample efficiency makes it impractical for the BEHAVIOR challenge. Moreover, online RL requires a heterogeneous compute setup: GPUs with RT Cores are needed for simulation, while GPUs with Tensor Cores are needed for model training and rollouts. Given these constraints, we instead adopt rejection sampling fine-tuning (RFT), a technique shown to be effective in both LLMs and VLMs (Ahn et al., 2024; Touvron et al., 2023; Azzolini et al., 2025).

An overview of our RFT setup is provided in Figure 2. Starting from the official human demonstration for each scene, we randomly perturb the robot’s initial pose and use our pre-trained policy to perform rollouts under these perturbed configurations. Successful rollouts are retained as additional demonstrations. We perform  $N = 3$  rounds of RFT in total, collecting on average  $T = 8500$  trajectories per round.

After post-training, our model achieves a validation Q-score of 0.22. RFT also provides an estimate of the theoretical upper bound on model performance by tracking all success rate across all past validation runs. The theoretical best validation Q-score we could achieve is 0.31 (Table 2). Due to time constraints, we were unable to fully close this gap, leaving additional headroom for further post-training.

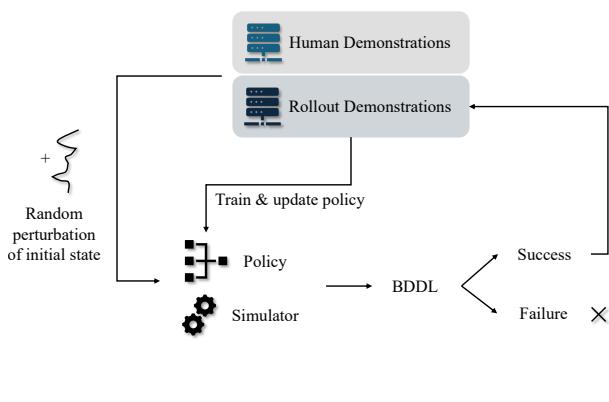
### 4.3 Ablations

Beyond pre-training and post-training, we find that seemingly low-level training and inference design decisions have a substantial impact on the performance. Table 3 reports a set of controlled ablations along four such axes: two that alter the training procedure, and two that modify only the inference strategy.

**Control mode (#1).** Temporal Ensemble and Receding Temporal configurations fail to produce stable closed-loop behavior and result in near-zero success rates. In contrast, the Receding Horizon scheme, which executes all the predicted action segment and performs re-planning after finishing manipulation, significantly improves performance. This result highlights the necessity of continuous feedback for long-

Table 2: Validation Q-scores across training stages.

Pre-training	Post-training	Theoretical Best
0.09	0.22	0.31




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**Algorithm 1** The RFT Algorithm

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1: Initialize  $\mathcal{D} \leftarrow$  human demos.
2: Initialize  $\pi_1$  to pre-trained  $\pi_{pt}$ .
3: for  $i = 1$  to  $N$  do
4:    $\mathcal{D}_i \leftarrow \emptyset$ 
5:   for  $t = 1$  to  $T$  do
6:     Sample initial state  $s_0$  from  $\mathcal{D}$ .
7:      $s'_0 \leftarrow s_0 + \epsilon$ .
8:     Rollout  $\tau$  from  $s'_0$  using  $\pi_i$ .
9:      $\mathcal{D}_i \leftarrow \mathcal{D}_i \cup \mathcal{D}_\tau$  if successful.
10:  end for
11:   $\mathcal{D} \leftarrow \mathcal{D} \cup \mathcal{D}_i$ .
12:  Train  $\pi_{i+1}$  on  $\mathcal{D}$ .
13: end for
14: return best  $\pi_i$  on validation.

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Figure 2: The RFT pipeline. We iteratively expand the training set with additional successful rollouts in the simulation environment using the latest policy.

horizon manipulation and shows that smoothing or averaging open-loop predictions quickly accumulates error.

**Action horizon (#2).** Varying the action horizon reveals a non-monotonic relationship between prediction length and downstream control performance. Moderate horizons strengthen long-horizon manipulation by allowing the model to anticipate multi-stage behaviors, whereas excessively long horizons introduce conflicting temporal dependencies that interfere with stable optimization. These findings indicate that the horizon length must be chosen to balance future awareness with the reliability of short-term control.

**Input modality (#3).** Replacing depth maps with reconstructed point clouds improves performance, which suggests that explicit geometric structure provides more informative cues for object-centric manipulation. However, the improvement over RGB-only inputs is limited, while the computational and latency overhead is considerable. Overall, explicit 3D geometry offers benefits in cluttered scenes, but the gains are not consistently large enough to justify the increased system complexity.

**Data Process (#4).** We further evaluate several data-processing strategies, including relative-action parameterization, 15 Hz temporal action subsampling, removal of proprioceptive state inputs, and weighted sampling to increase the Manipulation-Navigation ratio. Relative-action parameterization and the removal of state both destabilize training, suggesting that absolute action anchoring and explicit system observability are essential for stable closed-loop optimization. Action subsampling at 15 Hz accelerates execution but reduces temporal precision, leading to degraded manipulation accuracy. Finally, although reweighting the dataset toward manipulation segments shifts the empirical distribution, it yields no measurable improvement, indicating that simple resampling is insufficient to compensate for the structural difficulty and heterogeneous dynamics of long-horizon manipulation.

**Image resolution (#5).** Increasing the spatial resolution of both head and wrist views leads to substantial gains in performance. Low-resolution inputs of 224 by 224 pixels provide only coarse visual information, whereas high-resolution inputs of 720 by 480 pixels more than double the success rate. These results indicate that precise visual cues are critical for reliable manipulation in visually complex environments, and that high-fidelity perception plays an essential role in long-horizon tasks.

## 5 Conclusion

In this report, we presented our solution to the 2025 BEHAVIOR Challenge, adapting the publicly available  $\pi_{0.5}$  backbone to a demanding long-horizon household benchmark and systematically studying how pre-training task coverage, post-training, and inference-time design choices affect performance on all tasks. Our experiments reveal that scaling pre-training over more numerous and diverse BEHAVIOR tasks significantly generalizes and unlocks success on rare, compositional activities. We show that RFT as a post-training technique avoids the infrastructure issues from online RL yet yield trackable targets as well as significant performance boost.

We believe that combining strong VLA backbones with more structured long-horizon reasoning, richer post-training objectives, and better curriculum design will further close the gap between synthetic

Table 3: Ablation study of control mode, action horizon, input modality, and image resolution on the turning on radio task.

Settings	Control Mode	Action Horizon	Input Modality	Data Process	Image Resolution	Success Rate
#1	Temporal Ensemble	50	RGB	Absolute Action (30Hz) with State No weighting	Head:224 Wrist:224	0.00
	Receding Temporal					0.00
	Receding Horizon					<b>0.25</b>
#2	Receding Horizon	8	RGB	Absolute Action (30Hz) with State No weighting	Head:224 Wrist:224	0.00
		16				0.10
		50				0.25
		32				<b>0.30</b>
#3	Receding Horizon	32	RGB+Depth RGB+Point Cloud RGB	Absolute Action (30Hz) with State No weighting	Head:224 Wrist:224	0.20 0.20 <b>0.30</b>
		32	RGB	Relative Action Action Sampling (15Hz) w/o State Manip:Nav=2:1	Head:224 Wrist:224	0.00 0.00 0.00
						<b>0.30</b>
#4	Receding Horizon	32	RGB	Absolute Action (30Hz) with State No weighting	Head:224 Wrist:224 Head:720 Wrist:480	0.30 0.60
#5	Receding Horizon	32	RGB	Absolute Action (30Hz) with State No weighting		

benchmarks and real-world deployment, and we hope our empirical findings provide practical guidance for scaling foundation policies to complex, human-centric environments.

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## References

- Janice Ahn, Rishu Verma, Renze Lou, Di Liu, Rui Zhang, and Wenpeng Yin. Large language models for mathematical reasoning: Progresses and challenges. *arXiv preprint arXiv:2402.00157*, 2024.
- Alisson Azzolini, Junjie Bai, Hannah Brandon, Jiaxin Cao, Prithvijit Chattopadhyay, Huayu Chen, Jinju Chu, Yin Cui, Jenna Diamond, Yifan Ding, et al. Cosmos-reason1: From physical common sense to embodied reasoning. *arXiv preprint arXiv:2503.15558*, 2025.
- Kevin Black, Noah Brown, Danny Driess, Adnan Esmail, Michael Equi, Chelsea Finn, Niccolo Fusai, Lachy Groom, Karol Hausman, Brian Ichter, et al.  $\pi_0$ : A vision-language-action flow model for general robot control. *arXiv preprint arXiv:2410.24164*, 2024.
- Anthony Brohan, Noah Brown, Justice Carbajal, Yevgen Chebotar, Joseph Dabis, Chelsea Finn, Keerthana Gopalakrishnan, Karol Hausman, Alex Herzog, Jasmine Hsu, et al. Rt-1: Robotics transformer for real-world control at scale. *arXiv preprint arXiv:2212.06817*, 2022.
- Anthony Brohan, Noah Brown, Justice Carbajal, Yevgen Chebotar, Xi Chen, Krzysztof Choromanski, Tianli Ding, Danny Driess, Avinava Dubey, Chelsea Finn, et al. Rt-2: Vision-language-action models transfer web knowledge to robotic control. *arXiv preprint arXiv:2307.15818*, 2023.
- Kang Chen, Zhihao Liu, Tonghe Zhang, Zhen Guo, Si Xu, Hao Lin, Hongzhi Zang, Quanlu Zhang, Zhaofei Yu, Guoliang Fan, et al. pirl: Online rl fine-tuning for flow-based vision-language-action models. *arXiv preprint arXiv:2510.25889*, 2025.
- Zixuan Chen, Ze Ji, Jing Huo, and Yang Gao. Scar: Refining skill chaining for long-horizon robotic manipulation via dual regularization. *Advances in Neural Information Processing Systems*, 37:111679–111714, 2024.
- Moo Jin Kim, Karl Pertsch, Siddharth Karamcheti, Ted Xiao, Ashwin Balakrishna, Suraj Nair, Rafael Rafailov, Ethan Foster, Grace Lam, Pannag Sanketi, et al. Openvla: An open-source vision-language-action model. *arXiv preprint arXiv:2406.09246*, 2024.
- George Konidaris and Andrew Barto. Skill discovery in continuous reinforcement learning domains using skill chaining. *Advances in neural information processing systems*, 22, 2009.
- Chengshu Li, Ruohan Zhang, Josiah Wong, Cem Gokmen, Sanjana Srivastava, Roberto Martín-Martín, Chen Wang, Gabrael Levine, Wensi Ai, Benjamin Martinez, et al. Behavior-1k: A human-centered, embodied ai benchmark with 1,000 everyday activities and realistic simulation. *arXiv preprint arXiv:2403.09227*, 2024.
- Xingyu Lin, Zhiao Huang, Yunzhu Li, Joshua B Tenenbaum, David Held, and Chuang Gan. Diffskill: Skill abstraction from differentiable physics for deformable object manipulations with tools. *arXiv preprint arXiv:2203.17275*, 2022.
- Octo Model Team, Dibya Ghosh, Homer Walke, Karl Pertsch, Kevin Black, Oier Mees, Sudeep Dasari, Joey Hejna, Charles Xu, Jianlan Luo, Tobias Kreiman, You Liang Tan, Lawrence Yunliang Chen, Pannag Sanketi, Quan Vuong, Ted Xiao, Dorsa Sadigh, Chelsea Finn, and Sergey Levine. Octo: An open-source generalist robot policy. In *Proceedings of Robotics: Science and Systems (RSS)*, 2024.
- Delin Qu, Haoming Song, Qizhi Chen, Yuanqi Yao, Xinyi Ye, Yan Ding, Zhigang Wang, JiaYuan Gu, Bin Zhao, Dong Wang, et al. Spatialvla: Exploring spatial representations for visual-language-action model. *arXiv preprint arXiv:2501.15830*, 2025.
- Haochen Shi, Huazhe Xu, Samuel Clarke, Yunzhu Li, and Jiajun Wu. Robocook: Long-horizon elasto-plastic object manipulation with diverse tools. *arXiv preprint arXiv:2306.14447*, 2023.
- Chenrui Tie, Shengxiang Sun, Jinxuan Zhu, Yiwei Liu, Jingxiang Guo, Yue Hu, Haonan Chen, Junting Chen, Ruihai Wu, and Lin Shao. Manual2skill: Learning to read manuals and acquire robotic skills for furniture assembly using vision-language models. *arXiv preprint arXiv:2502.10090*, 2025.
- Hugo Touvron, Louis Martin, Kevin Stone, Peter Albert, Amjad Almahairi, Yasmine Babaei, Nikolay Bashlykov, Soumya Batra, Prajjwal Bhargava, Shruti Bhosale, et al. Llama 2: Open foundation and fine-tuned chat models. *arXiv preprint arXiv:2307.09288*, 2023.
- Michał Zawalski, William Chen, Karl Pertsch, Oier Mees, Chelsea Finn, and Sergey Levine. Robotic control via embodied chain-of-thought reasoning. *arXiv preprint arXiv:2407.08693*, 2024.
- Qingqing Zhao, Yao Lu, Moo Jin Kim, Zipeng Fu, Zhuoyang Zhang, Yecheng Wu, Zhaoshuo Li, Qianli Ma, Song Han, Chelsea Finn, et al. Cot-vla: Visual chain-of-thought reasoning for vision-language-action models. In *Proceedings of the Computer Vision and Pattern Recognition Conference*, pp. 1702–1713, 2025.