

Gemini Robotics: Bringing AI into the Physical World

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Recent advancements in large multimodal models have led to the emergence of remarkable generalist capabilities in digital domains, yet their translation to physical agents such as robots remains a significant challenge. Generally useful robots need to be able to make sense of the physical world around them, and interact with it competently and safely. This report introduces a new family of AI models purposefully designed for robotics and built upon the foundation of Gemini 2.0. We present Gemini Robotics, an advanced Vision-Language-Action (VLA) generalist model capable of directly controlling robots. Gemini Robotics executes smooth and reactive movements to tackle a wide range of complex manipulation tasks while also being robust to variations in object types and positions, handling unseen environments as well as following diverse, open vocabulary instructions. We show that with additional fine-tuning, Gemini Robotics can be specialized to new capabilities including solving long-horizon, highly dexterous tasks like folding an origami fox or playing a game of cards, learning new short-horizon tasks from as few as 100 demonstrations, adapting to completely novel robot embodiments including a bi-arm platform and a high degrees-of-freedom humanoid. This is made possible because Gemini Robotics builds on top of the Gemini Robotics-ER model, the second model we introduce in this work. Gemini Robotics-ER (Embodied Reasoning) extends Gemini’s multimodal reasoning capabilities into the physical world, with enhanced spatial and temporal understanding. This enables capabilities relevant to robotics including object detection, pointing, trajectory and grasp prediction, as well as 3D understanding in the form of multi-view correspondence and 3D bounding box predictions. We show how this novel combination can support a variety of robotics applications, e.g., zero-shot (via robot code generation), or few-shot (via in-context learning). We also discuss and address important safety considerations related to this new class of robotics foundation models. The Gemini Robotics family marks a substantial step towards developing general-purpose robots that realize AI’s potential in the physical world.

1. Introduction

The remarkable progress of modern artificial intelligence (AI) models – with pre-training on large-scale datasets – has redefined information processing, demonstrating proficiency and generalization across diverse modalities such as text, images, audio, and video. This has opened a vast landscape of opportunities for interactive and assistive systems within the digital realm, ranging from multimodal chatbots to virtual assistants. However, realizing the potential of general-purpose autonomous AI in the physical world requires a substantial shift from the digital world, where physically grounded AI agents must demonstrate robust human-level *embodied reasoning*: The set of world knowledge that encompasses the fundamental concepts which are critical for operating and acting in an inherently physically embodied world. While, as humans, we take for granted our embodied reasoning abilities – such as perceiving the 3D structure of environments, interpreting complex inter-object relationships, or understanding intuitive physics – these capabilities form an important basis for any embodied AI agent. Furthermore, an embodied AI agent must also go beyond passively understanding the spatial and physical concepts of the real world; it must also learn to take actions that have direct effects

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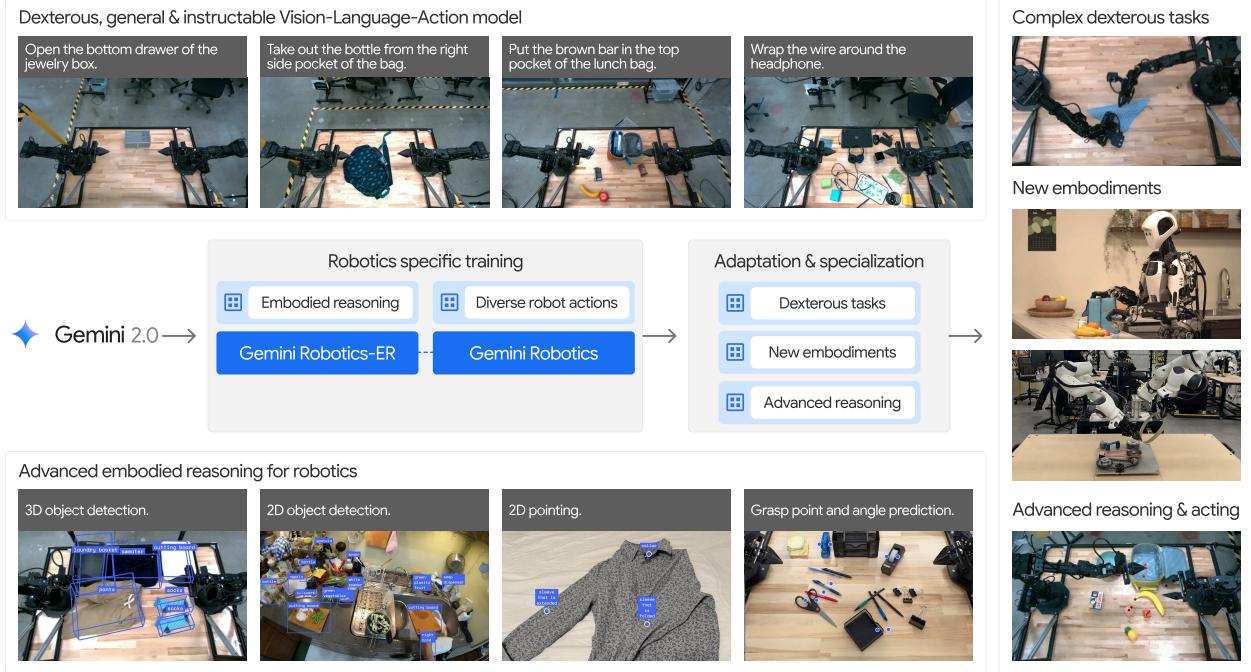


Figure 1 | Overview of the Gemini Robotics family of embodied AI models. Gemini 2.0 already exhibits capabilities relevant to robotics such as semantic safety understanding and long contexts. The robotics-specific training and the optional specialization processes enable the Gemini Robotics models to exhibit a variety of robotics-specific capabilities. The models generate dexterous and reactive motions, can be quickly adapted to new embodiments, and use advanced visuo-spatial reasoning to inform actions.

on their external environment, bridging the gap between passive perception and active physical interaction.

With the recent advancements in robotics hardware, there is exciting potential for creating embodied AI agents that can perform highly dexterous tasks. With this in mind, we ask: What would it take to endow a state-of-the-art digital AI model with the embodied reasoning capabilities needed to interact with our world in a general and dexterous manner?

Our thesis is predicated on harnessing the advanced multimodal understanding and reasoning capabilities inherent in frontier Vision-Language Models (VLMs), such as Gemini 2.0. The generalized comprehension afforded by these foundation models, with their ability to interpret visual inputs and complex text instructions, forms a powerful foundation for building embodied agents. This endeavor hinges on two fundamental components. First, Gemini needs to acquire robust embodied reasoning, gaining the ability to understand the rich geometric and temporal-spatial details of the physical world. Second, we must ground this embodied reasoning in the physical world by enabling Gemini to speak the language of physical actions, understanding contact physics, dynamics, and the intricacies of real-world interactions. Ultimately, these pieces must coalesce to enable fast, safe and dexterous control of robots in the real world.

To this end, we introduce the Gemini Robotics family of embodied AI models, built on top of Gemini 2.0, our most advanced multimodal foundation model. We first validate the performance and generality of the base Gemini 2.0's innate embodied reasoning capabilities with a new open-source general embodied reasoning benchmark, **ERQA**. We then introduce two models: The first model is **Gemini Robotics-ER**, a VLM with strong embodied reasoning capabilities at its core, exhibiting generalization across a wide range of embodied reasoning tasks while also maintaining its core foundation model

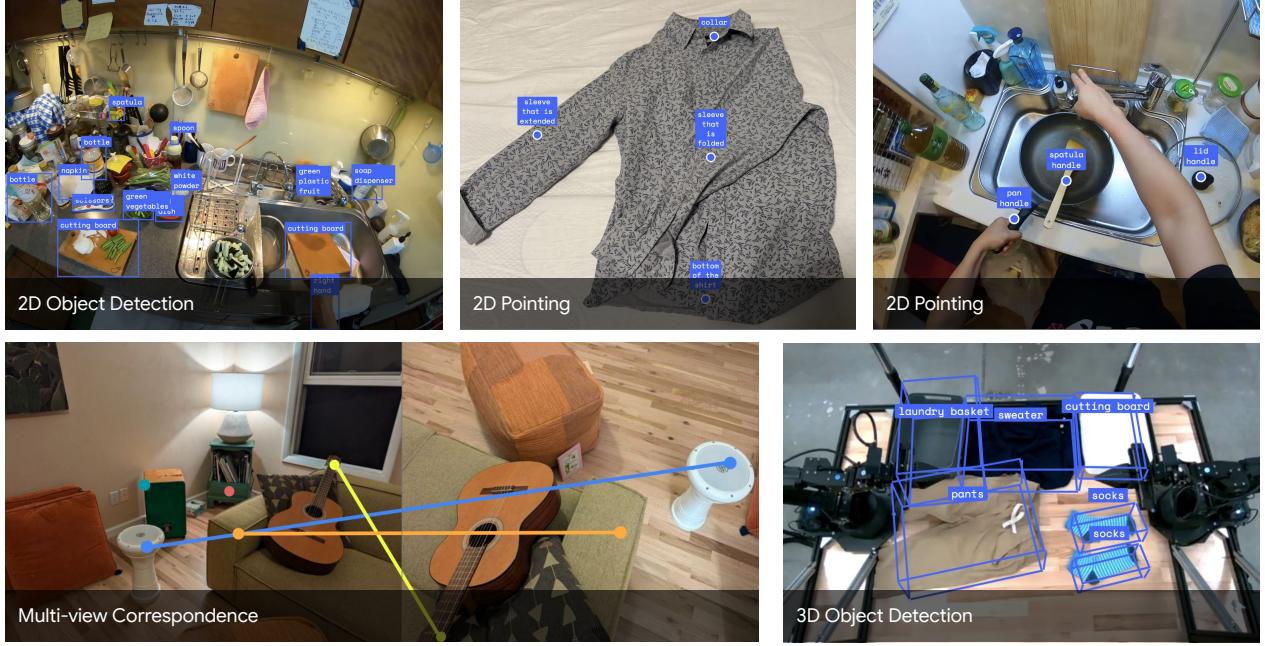


Figure 2 | Gemini 2.0 excels at embodied reasoning capabilities — detecting objects and points in 2D, leveraging 2D pointing for grasping and trajectories, and corresponding points and detecting objects in 3D. All results shown are obtained with Gemini 2.0 Flash.

capabilities. Gemini Robotics-ER exhibits strong performance on multiple capabilities critical for understanding the physical world, ranging from 3D perception to detailed pointing to robot state estimation and affordance prediction via code. The second model is **Gemini Robotics**, a state-of-the-art Vision-Language-Action (VLA) model that connects strong embodied reasoning priors to dexterous low-level control of real-world robots to solve challenging manipulation tasks. As a generalist VLA, Gemini Robotics can perform a wide array of diverse and complicated tasks, while also closely following language guidance and generalizing to distribution shifts in instructions, visuals, and motions. To emphasize the flexibility and generality of the Gemini Robotics models, we also introduce an optional specialization stage, which demonstrates how Gemini Robotics can be adapted for extreme dexterity, for advanced reasoning in difficult generalization settings, and for controlling completely new robot embodiments. Finally, we discuss the safety implications of training large robotics models such as the Gemini Robotics models, and provide guidelines for how to study such challenges in the context of VLAs. Specifically, this report highlights:

1. **ERQA**: An open-source benchmark specifically designed to evaluate embodied reasoning capabilities of multimodal models, addressing the lack of benchmarks that go beyond assessing atomic capabilities and facilitating standardized assessment and future research.
2. **Gemini Robotics-ER**: A VLM demonstrating enhanced embodied reasoning capabilities.
3. **Gemini Robotics**: A VLA model resulting from the integration of robot action data, enabling high-frequency dexterous control, robust generalization and fast adaptation across diverse robotic tasks and embodiments.
4. **Responsible Development**: We discuss and exercise responsible development of our family of models in alignment with Google AI Principles carefully studying the societal benefits and risks of our models, and potential risk mitigation.

The Gemini Robotics models serve as an initial step towards more generally capable robots. We believe that, ultimately, harnessing the embodied reasoning capabilities from internet scale data,

Trajectory Reasoning	Action Reasoning	Spatial Reasoning
 <p>Approximately which colored trajectory should the zipper follow to begin zipping up the suitcase?</p> <p>A. Blue B. Purple C. Green D. Red</p>	 <p>How should the person move the wrench so that it is ready to rotate the hex screw closest to it?</p> <p>A. Forward and right B. Up and left C. Forward and left D. None of the above</p>	 <p>There are 4 sinks in the picture. Which arrow points to the one that is closest to the viewer?</p> <p>A. Cyan B. Blue C. Red D. None of the arrows</p>

Figure 3 | Example questions from the Embodied Reasoning Question Answering (ERQA) benchmark, with answers in bold.

grounded with action data from real world interactions, can enable robots to deeply understand the physical world and act competently. This understanding will empower them to achieve even the most challenging goals with generality and sophistication that has so far seemed out of reach for robotic systems.

2. Embodied Reasoning with Gemini 2.0

Gemini 2.0 is a Vision-Language Model (VLM) that is capable of going beyond tasks that only require visual understanding and language processing. In particular, this model exhibits advanced *embodied reasoning* (ER) capabilities. We define ER as the ability of a Vision-Language Model to ground objects and spatial concepts in the real world, and the ability to synthesize those signals for downstream robotics applications. See some examples of such capabilities in Fig. 2. In Section 2.1, we first introduce a benchmark for evaluating a broad spectrum of ER capabilities and show that Gemini 2.0 models are state-of-the-art. In Section 2.2, we demonstrate the wide range of specific ER capabilities enabled by Gemini 2.0. Finally, in Section 2.3, we showcase how these capabilities can be put to use in robotics applications without the need for fine-tuning on robot action data, enabling use cases such as zero-shot control via code generation and few-shot robot control via in-context learning.

2.1. Embodied Reasoning Question Answering (ERQA) Benchmark

To capture progress in embodied reasoning for VLMs, we introduce ERQA, short for Embodied Reasoning Question Answering, a benchmark that focuses specifically on capabilities likely required by an embodied agent interacting with the physical world. ERQA consists of 400 multiple choice Visual Question Answering (VQA)-style questions across a wide variety of categories, including spatial reasoning, trajectory reasoning, action reasoning, state estimation, pointing, multi-view reasoning, and task reasoning. A breakdown of the distribution of question types is in Fig. 4. Of the 400 questions 28% have more than one image in the prompt — these questions that



Figure 4 | ERQA question categories.

Benchmark	Gemini				GPT		Claude
	1.5 Flash	1.5 Pro	2.0 Flash	2.0 Pro Experimental	4o-mini	4o	3.5 Sonnet
ERQA	42.3	41.8	46.3	48.3	37.3	47.0	35.5
RealworldQA (test)	69.0	64.5	71.6	74.5	65.0	71.9	61.4
BLINK (val)	59.2	64.4	65.0	65.2	56.9	62.3	60.2

Table 1 | Comparing VLMs on benchmarks that assess a wide range of embodied reasoning capabilities, including our new ERQA benchmark. Benchmarks are evaluated by accuracies of multiple-choice answers. Results obtained in Feb 2025.

require corresponding concepts across multiple images tend to be more challenging than single-image questions.

ERQA is complementary to existing VLM benchmarks, which tend to highlight more atomic capabilities (e.g., object recognition, counting, localization), but in most cases do not take sufficient account of the broader set of capabilities needed to act in the physical world. Fig. 3 shows some example questions and answers of our ERQA. Some questions require the VLM to recognize and register objects across multiple frames; others require reasoning about objects’ affordances and 3D relationships with the rest of the scene. Full details of the benchmark can be found at <https://github.com/embodiedreasoning/ERQA>.

We manually labeled all questions in ERQA to ensure correctness and quality. Images (not questions) in the benchmark are either taken by ourselves or sourced from these datasets: OXE (O’Neill et al., 2024), UMI Data (UMI-Data, 2024), MECCANO (Ragusa et al., 2021, 2022), HoloAssist (Wang et al., 2023), and EGTEA Gaze+ (Li et al., 2021). In Table 1, we report results of Gemini models and other models on ERQA, as well as on RealworldQA (XAI-org, 2024) and BLINK (Fu et al., 2024), two popular benchmarks that also measure spatial and image understanding capabilities. Specifically, we report results of Gemini 2.0 Flash, a powerful low-latency workhorse model and Gemini 2.0 Pro Experimental 02-05 (short as Gemini 2.0 Pro Experimental in the rest of the paper), the best Gemini model for complex tasks. Gemini 2.0 Flash and Pro Experimental achieve a new state-of-the-art on all three benchmarks in their respective model classes. We also note that ERQA is the most challenging benchmark across these three, making the performance here especially notable.

Gemini 2.0 models are capable of advanced reasoning — we found we can significantly improve Gemini 2.0’s performance on the benchmark if we use Chain-of-Thought (CoT) prompting (Wei et al., 2022), which encourages the model to output reasoning traces to “think” about a problem before choosing the multiple choice answer, instead of directly predicting the answer. We use the following instruction as the CoT prompt appended at the end of each question: “Reason step by step about the answer, and show your work, for each step. Only after that, proceed to the final answer.” Results are shown in Table 2. With CoT prompting, Gemini 2.0 Flash’s performance exceeds that of Gemini 2.0 Pro Experimental without CoT, and CoT further improves Gemini 2.0 Pro Experimental’s performance. We highlight two such reasoning traces in Fig. 5, questions that Gemini 2.0 Pro Experimental answered incorrectly without CoT, but correctly with CoT. The reasoning traces demonstrate Gemini 2.0 is able

Prompt Variant	Gemini		GPT		Claude
	2.0 Flash	2.0 Pro Experimental	4o-mini	4o	3.5 Sonnet
Without CoT	46.3	48.3	37.3	47.0	35.5
With CoT	50.3	54.8	40.5	50.5	45.8

Table 2 | Performances on the ERQA benchmark with and without Chain-of-Thought (CoT) prompting.

Question	Reasoning Trace	Question	Reasoning Trace
 <p>If the yellow robot gripper follows the yellow trajectory, what will happen?</p> <p>A. Robot puts the soda on the wooden steps. B. Robot moves the soda in front of the wooden steps. C. Robot moves the soda to the very top of the wooden steps. D. Robot picks up the soda can and moves it up.</p>	<p>Let's analyze the trajectory and the position of the soda can and the wooden steps.</p> <p>Step 1: Observe the starting point. The yellow trajectory starts at the green circle, which is around the soda can. This indicates the robot gripper is initially positioned to interact with the can.</p> <p>Step 2: Analyze the trajectory path. The yellow line moves upwards from the can, indicating a lifting motion. Then, it curves towards the wooden steps.</p> <p>Step 3: Observe the ending point. The trajectory ends at the purple circle, which is located on the first step of the wooden structure.</p> <p>Step 4: Combine the observations. The robot gripper starts at the can, moves upwards (picking up the can), and then moves towards the wooden steps, ending on the first step.</p> <p>Step 5: Deduce the outcome. Based on the trajectory, the robot will pick up the soda can and place it on the first step of the wooden structure.</p> <p>Final Answer: (A)</p>	 <p>How does the bottom dial need to move in order to match the top two dials?</p> <p>A. Half turn clockwise. B. Quarter turn counterclockwise. C. Quarter turn clockwise. D. No change needed</p>	<p>Let's analyze the position of the bottom dial compared to the top two dials.</p> <p>Step 1: Observe the top two dials. Both the top and middle dials have their indicator lines pointing straight up.</p> <p>Step 2: Observe the bottom dial. The bottom dial has its indicator line pointing to the left.</p> <p>Step 3: Determine the necessary movement. To make the bottom dial's indicator line point straight up like the other two, it needs to be rotated to the right.</p> <p>Step 4: Quantify the movement. A full circle is 360 degrees. A quarter turn is $360/4 = 90$ degrees. The bottom dial needs to move 90 degrees to the right.</p> <p>Step 5: Select the correct option. A 90-degree rotation to the right is a quarter turn clockwise.</p> <p>Final Answer: (C)</p>

Figure 5 | Examples of questions and reasoning traces with Gemini 2.0 Pro Experimental. Red answers were obtained without the CoT prompt; green answers obtained with CoT prompt.

to 1) precisely ground its spatial understanding in observations in the image and 2) leverage such grounding to perform complex, step-by-step embodied reasoning.

2.2. Gemini 2.0’s Embodied Reasoning Capabilities

In this section, we illustrate some of Gemini 2.0’s embodied reasoning capabilities in more detail. We also introduce Gemini Robotics-ER, a version of Gemini 2.0 Flash that has enhanced embodied reasoning. These can be used in robotics applications without the need for any additional robot-specific data or training. Gemini 2.0 can understand a variety of 2D spatial concepts in images.

- Object Detection:** Gemini 2.0 can perform open-world 2D object detection, providing precise 2D bounding boxes with queries that can be explicit (e.g., describing an object name) or implicit (categories, attributes, or functions).
- Pointing:** Given any natural language description, the model is able to point to explicit entities like objects and object parts, as well as implicit notions such as affordances (where to grasp, where to place), free space and spatial concepts. See Table 3 for quantitative evaluations.
- Trajectory Prediction:** Gemini 2.0 can leverage its pointing capabilities to produce 2D motion trajectories that are grounded in its observations. Trajectories can be based, for instance, on a description of the physical motion or interaction.
- Grasp Prediction:** This is a new feature introduced in Gemini Robotics-ER. It extends Gemini 2.0’s pointing capabilities to predict top-down grasps.

Gemini 2.0 is also capable of 3D spatial reasoning (Chen et al., 2024; Hwang et al., 2024). With the ability to “see in 3D”, Gemini 2.0 can better understand concepts like sizes, distances, and orientations, and it can leverage such understanding to reason about the state of the scene and actions to perform.

- Multi-View Correspondence:** A natural way of representing 3D information with images is through multi-view (e.g., stereo) images. Gemini 2.0 can understand 3D scenes from multi-view images and predict 2D point correspondences across multiple camera views of the same scene.
- 3D Bounding Box Detection:** This 3D understanding applies to single images as well - Gemini 2.0 can directly predict metric 3D bounding boxes from monocular images. Like 2D Detection and Pointing capabilities, Gemini 2.0 can detect objects by open-vocabulary descriptions.

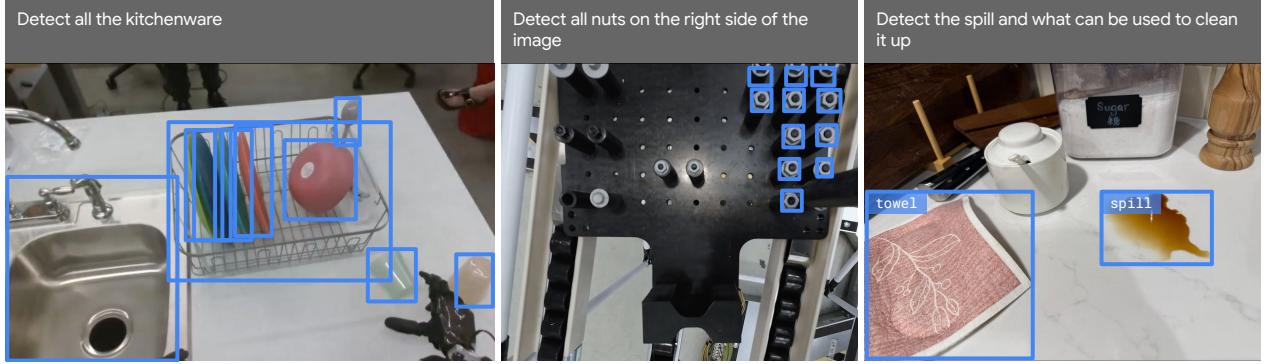


Figure 6 | 2D Detection examples with Gemini 2.0 Flash. Left: detect by object category. Middle: detect by spatial description. Right: detect by affordance. Predicted object labels are not shown for left and middle images to reduce visual clutter.



Figure 7 | Gemini 2.0 can predict 2D points from natural language queries. Examples are obtained with Gemini 2.0 Flash. Predicted point labels are not visualized.

While it is possible to create expert models for each of these tasks individually, fusing them in a single foundation model, such as Gemini 2.0, allows the model to perform embodied reasoning tasks with open-world natural language instructions, respond to feedback and sustain multi-turn interactions. In particular, Gemini 2.0 can combine scene understanding with reasoning to solve more complex tasks, such as writing robot code (see Section 2.3).

Below we present detailed quantitative and qualitative evaluations of these capabilities with Gemini 2.0 models (Flash, and Pro Experimental), as well as comparisons with other VLMs where appropriate. For some capabilities, we also present results on Gemini Robotics-ER. You can find code and prompt examples on how to prompt Gemini 2.0 to elicit these capabilities [here](#).

Object Detection. Gemini 2.0 can predict 2D object bounding boxes from natural language queries. In Fig. 6, we show multiple 2D detection examples with Gemini 2.0 Flash on images that a robot might see. Gemini 2.0 represents 2D bounding boxes with the convention y_0, x_0, y_1, x_1 . We can prompt Gemini 2.0 to detect everything in a scene (examples in Fig. 2). The model can also detect specific objects by their descriptions — for example, “detect all the kitchenware” in Fig. 6. These descriptions can contain spatial cues as well — “detecting nuts on the right side of the image” in the middle example. Finally, we can prompt Gemini 2.0 to detect objects by their affordances. In the right example of Fig. 6, we ask Gemini 2.0 to detect the spill and “what can be used to clean it up”. Gemini 2.0 is able to detect both the spill and the towel, without being specified explicitly. These examples showcase the benefit of combining precise localization capabilities with general-purpose VLMs, where

Benchmark	Gemini			GPT		Claude	Molmo	
	Gemini Robotics-ER	2.0 Flash	2.0 Pro Experimental	4o-mini	4o	3.5 Sonnet	7B-D	72B
Paco-LVIS	71.3	46.1	45.5	11.8	16.2	12.4	45.4	47.1
Pixmo-Point	49.5	25.8	20.9	5.9	5.0	7.2	14.7	12.5
Where2Place	45.0	33.8	38.8	13.8	20.6	16.2	45	63.8

Table 3 | 2D Pointing Benchmarks evaluating open-vocabulary pointing capabilities. Scores are accuracies (1 if predicted point is within the ground truth region mask, 0 otherwise).



Figure 8 | Gemini 2.0 can predict 2D trajectories by first predicting start and end points. Examples are obtained with Gemini 2.0 Flash. Predicted point labels are not visualized.

Gemini’s open-vocabulary and open-world reasoning enables a level of semantic generalization that is difficult to achieve with special-purpose expert models.

2D Pointing. For some use cases, points can offer a more flexible and precise representation for image understanding and robot control than bounding boxes. We illustrate Gemini 2.0’s pointing capabilities in various robot manipulation scenes (Fig. 7). The model represents points as y, x tuples. Similar to 2D object detection, Gemini 2.0 can point to any object described by open-vocabulary language. Gemini 2.0 can localize not only entire objects, but also object parts, such as a spoon handle (Fig. 7, left). Additionally, Gemini 2.0 can point to spatial concepts, e.g., an “empty area on the table left of the pan” (Fig. 7, left) or “where a new can should be placed following the pattern of the existing eight cans” (Fig. 7, middle). It can also infer affordances; for example, when asked to “point to where a human would grasp this to pick it up”, the model correctly identifies the mug handle (Fig. 7, right).

We quantitatively evaluate Gemini 2.0’s pointing performance in Table 3 using three benchmarks: Paco-LVIS (Ramanathan et al., 2023) for object part pointing on natural images, Pixmo-Point (Deitke et al., 2024) for open-vocabulary pointing on web images, and Where2place (Yuan et al., 2024) for free-space pointing in indoor scenes. See Appendix B.2 for details on how we benchmark pointing against other models. Gemini 2.0 significantly outperforms state-of-the-art vision-language models (VLMs) like GPT and Claude. Gemini Robotics-ER surpasses Molmo, a specialized pointing VLM, in two of the three subtasks.

2D Trajectories. Gemini 2.0 can leverage its pointing capabilities to predict 2D trajectories that connect multiple points together. While Gemini 2.0 cannot perform complex motion planning (e.g., to avoid obstacles), it can still generate useful trajectories that are grounded in the observed images. We showcase some examples in Fig. 8. In the left and middle images, Gemini 2.0 interpolates a

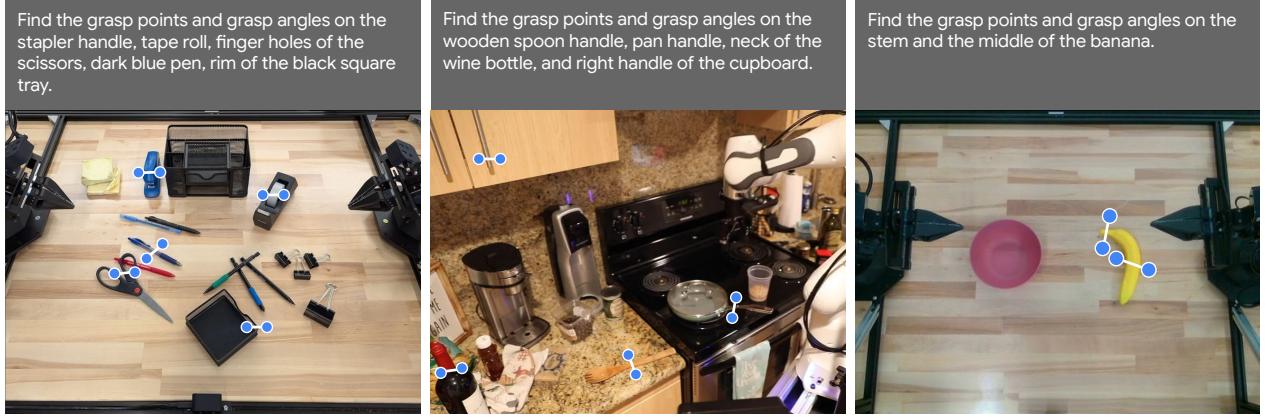


Figure 9 | Gemini Robotics-ER can predict top-down grasps by leveraging Gemini 2.0’s 2D pointing capability. Examples are obtained with Gemini Robotics-ER.

reasonable trajectory from a human hand in the ego-centric video to a tool that it may grasp. In the right image, Gemini 2.0 predicts a series of waypoints that, if followed by the robot gripper, would wipe the spilled area of a tray. Gemini 2.0’s trajectory prediction capabilities exhibit world knowledge about motion and dynamics which is a fundamental capability for robotics. We capitalize on these nascent trajectory understanding capabilities to tie actions to vision and language capabilities in a much stronger fashion in Section 4.2.

Top-Down Grasps. Gemini 2.0’s semantic pointing capabilities can be naturally extended to top-down grasping poses, represented as y , x , and a rotation angle θ . This capability is further improved in Gemini Robotics-ER, as shown in Fig. 9. For example, we can prompt for a grasp either on the stem or the center of the banana (right image). We show how such grasp predictions can be directly used for downstream robot control on real robots in Section 2.3.

Multi-view Correspondence. Gemini can also understand the 3D structure of the world. One example is its ability to understand a 3D scene from multiple views. For instance, with an initial image annotated with a list of points and a new image of the same scene from a different view, we can ask Gemini 2.0 which of the points from the initial image are still visible in the second image and we can query the coordinates of those points. From the examples in Fig. 10, we observe that Gemini 2.0 can perform multi-view correspondence across dramatically different views. In the top image pair, the model correctly predicts that the red point refers to an object held by the human in these egocentric images, even though the view of the rest of the scene has changed significantly. In the bottom image pair, the model correctly predicts that the orange point is not visible in the second image. Such multi-view understanding is useful for robotics domains where a robot can use Gemini 2.0 to reason about multiple image streams (e.g., stereo views, head and wrist views) to better understand the 3D spatial relationships of its observations.

3D Detection. Gemini 2.0 can also predict metric 3D bounding boxes from single images. Similar to its 2D detection capabilities, Gemini 2.0’s 3D detection capability is also open-vocabulary, as illustrated in Fig. 11. In Table 4, we report Gemini 2.0’s 3D detection performance using SUN-RGBD (Song et al., 2015), a popular dataset and benchmark for 3D object detection and scene understanding, and compare it with baseline expert models (ImVoxelNet (Rukhovich et al., 2022), Implicit3D (Zhang et al., 2021), and Total3DUnderstanding (Nie et al., 2020)). Gemini 2.0’s 3D detection performance is comparable to existing state-of-the-art expert models, with Gemini Robotics-ER achieving a new state-of-the-art on the SUN-RGBD benchmark. While these baselines work with a closed set of categories, Gemini allows for open-vocabulary queries.

Benchmark	Gemini			Specialized Expert Models		
	Gemini Robotics-ER	2.0 Flash	2.0 Pro Experimental	ImVoxelNet	Implicit3D	Total3DU
SUN-RGBD AP@15	48.3	30.7	32.5	43.7*	24.1	14.3

Table 4 | Gemini Robotics-ER achieves a new state-of-the-art performance on the SUN-RGBD 3D object detection benchmark. (* ImVoxelNet (Rukhovich et al., 2022) performance measured on an easier set of 10 categories).



Figure 10 | Gemini 2.0 can understand 3D scenes by correlating 2D points across different views. For each image pair, the left image with the point coordinates and the right image without coordinates are given, and the model predicts which of the labeled points in the left image are visible in the right image, as well as the coordinates of the visible points in the right image. Examples are obtained with Gemini 2.0 Flash.

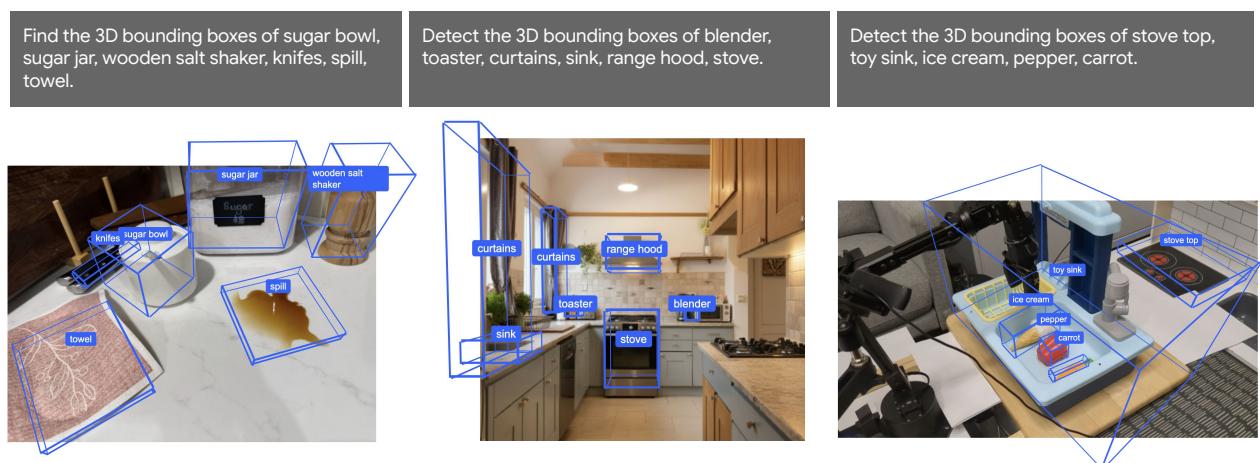


Figure 11 | Gemini 2.0 can directly predict open-vocabulary 3D object bounding boxes. Examples are obtained with Gemini 2.0 Flash.

2.3. Gemini 2.0 Enables Zero and Few-Shot Robot Control

Gemini 2.0’s embodied reasoning capabilities make it possible to control a robot without it ever having been trained with any robot action data. It can perform all the necessary steps, perception, state estimation, spatial reasoning, planning and control, out of the box. Whereas previous work needed to compose multiple models to this end (Ahn et al., 2022; Kwon et al., 2024; Liang et al., 2023; Vemprala et al., 2023), Gemini 2.0 unites all required capabilities in a single model.

Below we study two distinct approaches: zero-shot robot control via code generation, and few-shot control via in-context learning (also denoted as “ICL” below) - where we condition the model on a handful of in-context demonstrations for a new behavior. Gemini Robotics-ER achieves good performance across a range of different tasks in both settings, and we find that especially zero-shot robot control performance is strongly correlated with better embodied understanding: Gemini Robotics-ER, which has received more comprehensive training to this end, improves task completion by almost 2x compared to Gemini 2.0.

Zero-shot Control via Code Generation. To test Gemini 2.0’s zero-shot control capabilities, we combine its innate ability to generate code with the embodied reasoning capabilities described in Section 2.2. We conduct experiments on a bimanual ALOHA 2 (Team et al., 2024; Zhao et al., 2025) robot. To control the robot, Gemini 2.0 has access to an API (Arenas et al., 2023; Kwon et al., 2024; Liang et al., 2023) that can move each gripper to a specified pose, open and close each gripper, and provide a readout of the current robot state. The API also provides functions for perception; no external models are called, instead Gemini 2.0 itself detects object bounding boxes, points on objects, and generates the top down grasp pose as described in Section 2.2.

During an episode, Gemini 2.0 is initially passed a system prompt, a description of the robot API, and the task instructions. Then Gemini 2.0 iteratively takes in images that show the current state of the scene, the robot state, and execution feedback, and outputs code that is executed in the environment to control the robot. The generated code uses the API to understand the scene and move the robot and the execution loop allows Gemini 2.0 to react and replan when necessary (e.g., Fig. 34). An overview of the API and episodic control flow is given in Fig. 12.

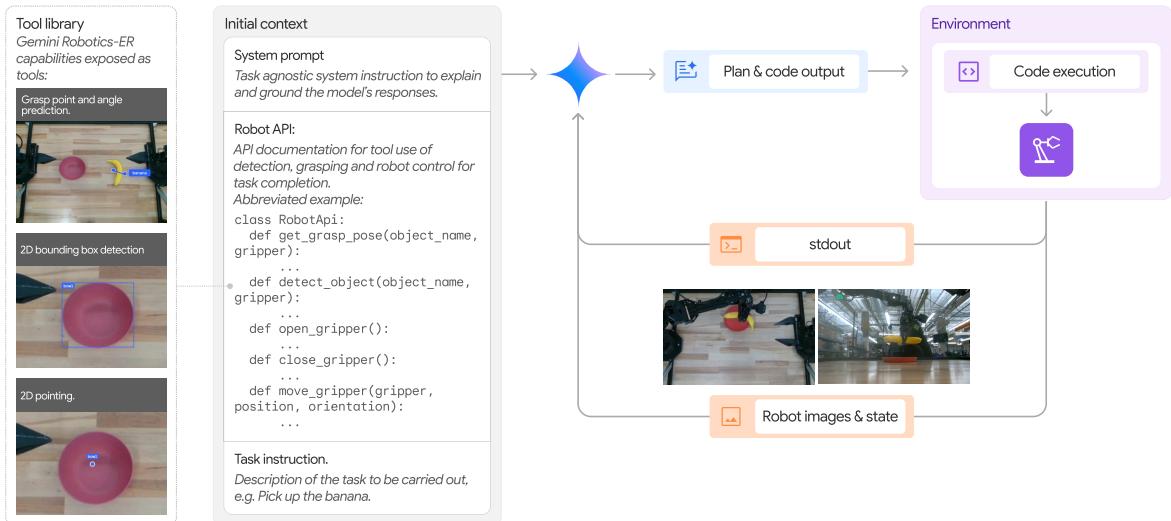


Figure 12 | Overview of the perception and control APIs, and agentic orchestration during an episode. This system is used for zero-shot control.

Table 5 presents results across a set of manipulation tasks in simulation. These tasks were chosen

to capture performance across a spectrum of difficulty and objects: from simple grasping (lift a banana) to long horizon multi-step, multi-task manipulation (put a toy in a box and close the box). See Appendix B.3.1 for full descriptions. Gemini 2.0 Flash succeeds on average 27% of the time, although it can be as high as 54% for easier tasks. Gemini Robotics-ER, performs almost twice as well as 2.0 Flash, successfully completing 53% of the tasks on average. The enhanced embodied reasoning capabilities of the Gemini Robotics-ER model have clearly benefited the downstream robotic tasks.

System		Sim Task Success Rate (%)								
Model	Context	Avg.	Banana Lift	Banana in Bowl	Mug on Plate	Bowl on Rack	Banana Handover	Fruit Bowl	Pack Toy	
2.0 Flash	Zero-shot	27	34	54	46	24	26	4	0	
Gemini Robotics-ER	Zero-shot	53	86	84	72	60	54	16	0	
2.0 Flash	ICL	51	94	90	36	16	94	0	26	
Gemini Robotics-ER	ICL	65	96	96	74	36	96	4	54	

Table 5 | Success rates on the ALOHA 2 Sim Task suite. Reported numbers are the average success rate over 50 trials with random initial conditions.

Table 6 shows results on a real ALOHA 2 robot. The success rate for banana handover is lower compared to simulation due to calibration imperfections and other sources of noise in the real world. For a harder and more dexterous task: Gemini Robotics-ER is currently unable to perform dress folding, mostly due to its inability to generate precise enough grasps.

Real Task Success Rate (%)				
Context	Avg.	Banana Handover	Fold Dress	Wiping
Zero-shot	25	30	0	44
ICL	65	70	56	67

Table 6 | Real world success rates of Gemini Robotics-ER on ALOHA 2 tasks. Reported rates are the average over 10 trials for banana handover and 9 for fold dress and wiping. For tasks that require dexterous motions, the zero-shot success rate is not high, but they will be significantly improved in the Gemini Robotics model (Sec. 3).

Few-shot control via in-context examples. The previous results demonstrated how Gemini Robotics-ER can be effectively used to tackle a series of tasks entirely zero-shot. However, some dexterous manipulation tasks are beyond Gemini 2.0’s current ability to perform zero-shot. Motivated by such cases, we demonstrate that the model can be conditioned on a handful of in-context demonstrations, and can then immediately emulate those behaviors. Instead of generating code, as in the previous examples, we instead prompt the model to generate trajectories of end-effectors poses directly, following the examples in the demonstrations.

We extend the method proposed in (Di Palo and Johns, 2024), which translates k teleoperated trajectories of robot actions into a list of objects and end-effectors poses, tokenizing them as text and adding them to the prompt (Fig. 13). Thanks to the embodied reasoning abilities of Gemini Robotics-ER, we do not need any external models to extract visual keypoints and object poses (as was done in the referenced work); Gemini Robotics-ER can do this itself. In addition to observations and actions, we interleave descriptions of the performed actions in language that elicits reasoning at inference time in the model. The model emulates the natural language reasoning from the in-context trajectories and becomes better at, for example, understanding which arm to use when, or more accurately predicting where to interact with objects. One advantage of using a large multimodal model

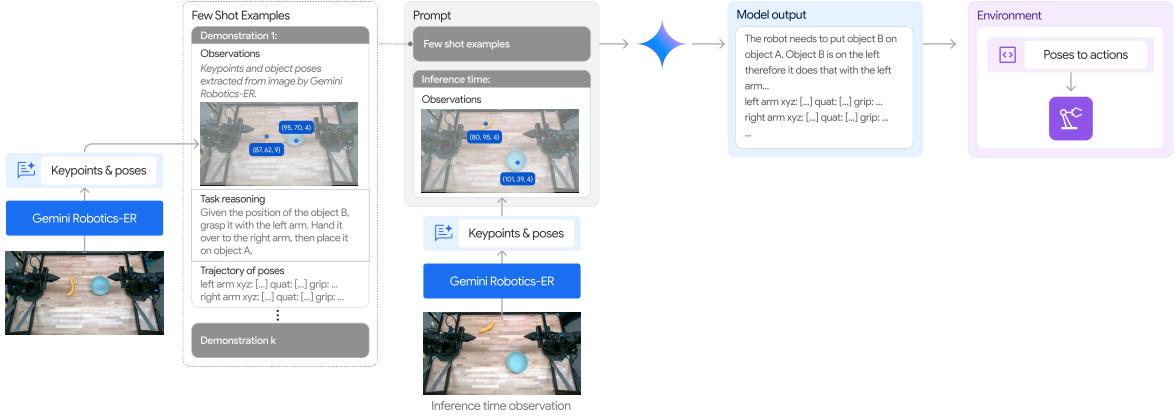


Figure 13 | Overview of few-shot in-context learning pipeline. Gemini can receive observations, language instructions and trajectories in the prompt, and generate new language reasoning and trajectories for unseen instances of the tasks.

is the ability to condition its behavior on observations, actions and language, with the combination of all outperforming any modality in isolation.

The results using this approach (with 10 demonstrations) are shown in Table 5 and Table 6. Both Gemini 2.0 Flash and Gemini Robotics-ER are able to effectively use demonstrations entirely in-context to improve performance. Gemini 2.0 Flash’s performance reaches 51% in simulation, and Gemini Robotics-ER achieves 65% in both simulation and the real world. Most of the performance improvements with respect to the zero-shot code generation approach comes from more dexterous tasks, like handover of objects, folding a dress, or packing a toy, where demonstrations can condition the model to output more precise, bimanual trajectories.

This set of experiments suggests that Gemini 2.0 Flash and its ER enhanced variant, Gemini Robotics-ER, can be used directly to control robots, as a perception module (e.g., object detection), a planning module (e.g., trajectory generation), and/or to orchestrate robot movements by generating and executing code. It also shows strong correlation between the model performance of embodied reasoning capabilities and the downstream robotic control. At the same time, our experiments demonstrate that the model is also able to tap into the power of in-context learning to learn from just a few demonstrations and boost performance on more dexterous and bimanual tasks, such as folding clothes, by directly outputting trajectories of end-effectors poses. However, as a VLM, there are inherent limitations for robot control, especially for more dexterous tasks, due to the intermediate steps needed to connect the model’s innate embodied reasoning capabilities to robotic actions. In the next section, we will introduce Gemini Robotics, an end-to-end Vision-Language-Action Model that enables more general-purpose and dexterous robot control.

3. Robot Actions with Gemini Robotics

In this section, we present Gemini Robotics, a derivative of Gemini that has been fine-tuned to predict robot actions directly. Gemini Robotics is a general-purpose model capable of solving dexterous tasks in different environments and supporting different robot embodiments. We first study the model after training on a large and diverse dataset consisting of action-labeled robot data as well as other multimodal data. The resulting model can solve a large variety of short-horizon dexterous tasks out of the box (Section 3.2), closely follows natural language instructions (Section 3.3) and inherits Gemini Robotics-ER generalization capabilities, showing robustness to visual variations of the scene, object

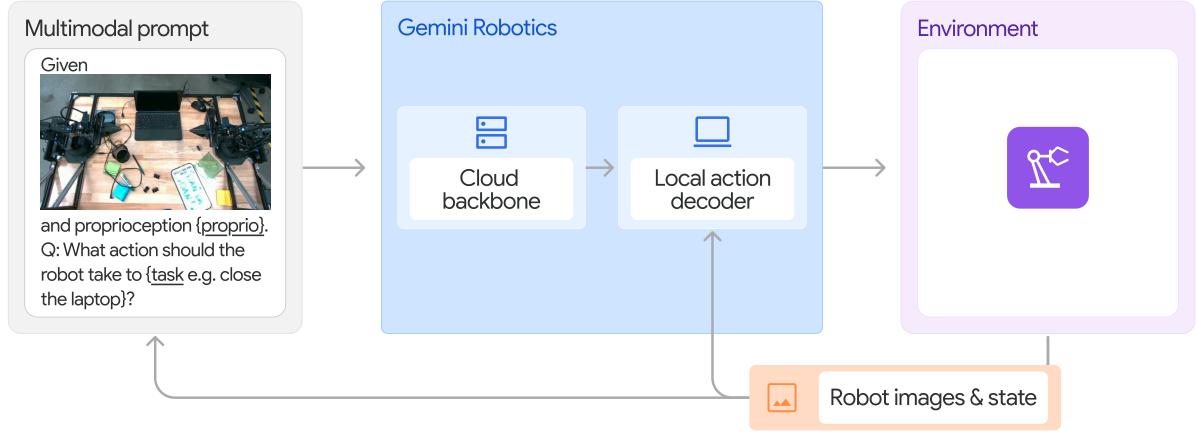


Figure 14 | Overview of the architecture, input and output of the Gemini Robotics model. Gemini Robotics is a derivative of Gemini fine-tuned to predict robot actions. The model ingests a multimodal prompt consisting of a set of images of the current status of the scene and a text instruction of the task to perform and it outputs action chunks that are executed by the robot. The model is made up of two components: a VLA backbone hosted in the cloud (Gemini Robotics backbone) and a local action decoder running on the robot’s onboard computer (Gemini Robotics decoder).

positions and instances (Section 3.4). In Section 4, we further test the limits of Gemini Robotics, and specialize it to challenging highly dexterous long-horizon tasks (Section 4.1), and to more extreme generalization scenarios (Section 4.2). We also investigate rapid adaptation to novel dexterous tasks (Section 4.3) as well as adaptation to embodiments with completely new form factors, actions and observations (Section 4.4).

3.1. Gemini Robotics: Model and Data

Model. Inference in large VLMs like Gemini Robotics-ER is often slow and requires special hardware. This can cause problems in the context of VLA models, since inference may not be feasible to be run onboard, and the resulting latency may be incompatible with real-time robot control. Gemini Robotics is designed to address these challenges. It consists of two components: a VLA backbone hosted in the cloud (Gemini Robotics backbone) and a local action decoder running on the robot’s onboard computer (Gemini Robotics decoder). The Gemini Robotics backbone is formed by a distilled version of Gemini Robotics-ER and its query-to-response latency has been optimized from seconds to under 160ms. The on-robot Gemini Robotics decoder compensates for the latency of the backbone. When the backbone and local decoder are combined, the end-to-end latency from raw observations to low-level action chunks is approximately 250ms. With multiple actions in the chunk (Zhao et al., 2023), the effective control frequency is 50Hz. The overall system not only produces smooth motions and reactive behaviors despite the latency of the backbone, but also retains the backbone’s generalization capabilities. An overview of our model architecture is available in Fig. 14.

Data. We collected a large-scale teleoperated robot action dataset on a fleet of ALOHA 2 robots (Team et al., 2024; Zhao et al., 2025) over 12 months, which consists of thousands of hours of real-world expert robot demonstrations. This dataset contains thousands of diverse tasks, covering scenarios with varied manipulation skills, objects, task difficulties, episode horizons, and dexterity requirements. The training data further includes non-action data such as web documents, code, multi-modal content (image, audio, video), and embodied reasoning and visual question answering data. This improves the



Figure 15 | A robot’s movement in a few example tasks that require dexterous manipulation in cluttered environments. From top to bottom: “open the eyeglasses case”, “pour pulses”, “unfasten file folder”, “wrap headphone wire”.

model’s ability to understand, reason about, and generalize across many robotic tasks, and requests.

Baselines. We compare Gemini Robotics to two state-of-the-art models: The first one is π_0 *re-implement*, which is our re-implementation of the open-weights state-of-the-art π_0 VLA model (Beyer et al., 2024; Black et al., 2024). We train π_0 *re-implement* on our diverse training mixture and find this model to outperform the public checkpoint released by the authors, and hence, report it as the most performant VLA baseline in our experiments (see Appendix C.2 for more details). The second is a multi-task diffusion policy (Chi et al., 2024) (inspired by ALOHA Unleashed (Zhao et al., 2025) but modified to be task-conditioned), a model that has been shown to be effective in learning dexterous skills from multi-modal demonstrations. Both baselines were trained to convergence using the *same composition* of our diverse data mixture. Gemini Robotics runs primarily in the cloud with a local action decoder, whereas both baselines run locally on a workstation equipped with an Nvidia RTX 4090 GPU. All empirical evidence presented in this section is based on rigorous real-world robot experiments, with A/B testing and statistical analysis (more details in Appendix C.1).

3.2. Gemini Robotics can solve diverse dexterous manipulation tasks out of the box

In our first set of experiments, we demonstrate that Gemini Robotics can solve a wide range of dexterous tasks. We evaluate the performance of this model on short-horizon dexterous tasks, and compare to state-of-the-art multi-task baselines. We evaluate all models out of the box, i.e., without any task-specific fine-tuning or additional prompting, on 20 tasks sampled from our dataset in Section 3.1. We choose diverse scene setups (some of them illustrated in Fig. 15), spanning a laundry room (e.g., “fold pants”), kitchen (e.g., “stack measuring cup”), cluttered office desk (e.g., “open pink folder”), and other day-to-day activities (e.g., “open glasses case”). These selected tasks also require varying

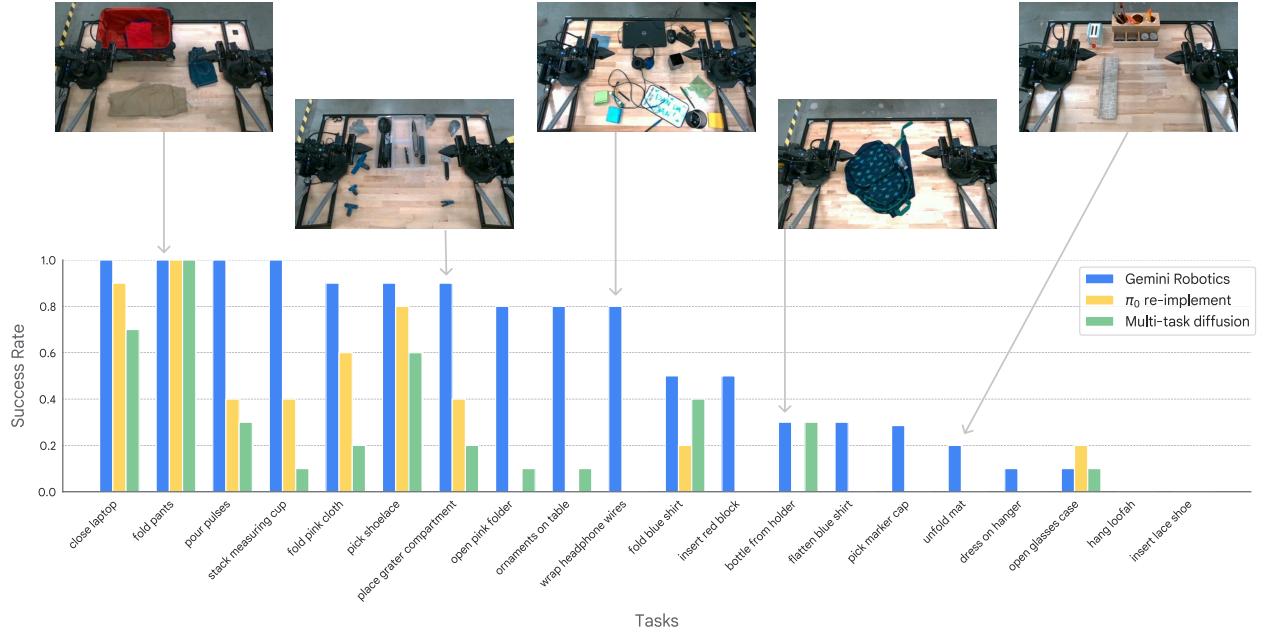


Figure 16 | Gemini Robotics can solve a wide variety of tasks out of the box. We sample 20 tasks from the dataset, which require varying levels of dexterity, and evaluate our model and the baselines on them. Gemini Robotics significantly outperforms the baselines.

levels of dexterity – from simple pick-and-place (e.g., “pick the shoe lace from the center of the table”) to dexterous manipulation of deformable objects that requires two-hand coordination (e.g., “wrap the wire around the headphone”). We show examples of our model rollouts of these tasks in Fig. 15 and full list of tasks in Appendix C.1.1.

Fig. 16 summarizes the performance of our model and the baselines. We find that the Gemini Robotics model is proficient at half of the tasks out of the box with a success rate exceeding 80%. Notably, our model excels at deformable object manipulation (“fold pink cloth”, “wrap the wire around the headphone”), while the baselines struggle with these tasks. For the more challenging tasks, (e.g., “open pink folder”, “insert red block”, “wrap the wire around the headphone”), we find that Gemini Robotics is the only method that can achieve non-zero success, highlighting that a combination of a high-capacity model architecture along with high-quality diverse data across all modalities (vision, language, and action) is essential for multi-task policy learning. Finally, we find that some of the most dexterous tasks are still quite challenging to learn purely from the multi-task setup (e.g., “insert shoe lace”): we discuss our specialization recipe for Gemini Robotics to solve these and longer-horizon challenging tasks in Section 4.1.

3.3. Gemini Robotics can closely follow language instructions

The second set of experiments tests the model’s ability to follow natural language instructions. We pick 25 language instructions to be evaluated in five diverse evaluation scenes, including training scenes as well as novel scenes with unseen objects and receptacles (details in Appendix C.1.2). The evaluation focuses on language commands that must be precisely followed (e.g., “Place the blue clip to the right of the yellow sticky notes”) – in contrast to open-ended abstract instructions like “clean the table”). We visualize rollouts and report the binary task success rates in Fig. 17.

Our experiments suggest that strong steerability arises from a combination of high-quality diverse data and a capable vision-language backbone. Gemini Robotics and π_0 re-implement outperform the



Figure 17 | Gemini Robotics can precisely follow novel language instructions in cluttered scenes which were never seen during training. Left: scene including objects seen during training. Middle: scene including novel objects. Right: success rate on “Pick” and “Pick and Place” tasks with detailed instructions for the new objects.

diffusion baseline, even in simple in-distribution scenes, suggesting that a strong language encoder is required. However, especially in challenging scenes with novel objects and fine-grained instructions (e.g., “Place the toothpaste in the bottom compartment of the caddy”), we find that Gemini Robotics is more effective than either baseline (Fig. 17). While the PaliGemma-based π_0 re-implement correctly approaches objects that were seen during training, it struggles with interpreting descriptive language attributes (e.g., “top black container”, “blue clip”) and fails to solve tasks with unseen objects and language descriptors.

3.4. Gemini Robotics brings Gemini’s generalization to the physical world

Lack of robust generalization is a key bottleneck for large-scale deployment of robots in domestic and industrial applications. In the final set of experiments, we evaluate Gemini Robotics’s ability to deal with variations along three axes that have been considered important in prior work (Gao et al., 2025).

Visual Generalization: The model should be invariant to visual changes of the scene that do not affect the actions required to solve the task. These visual changes can include variations in background, lighting conditions, distractor objects or textures.

Instruction Generalization: The model should understand invariance and equivalence in natural language instructions. Going beyond fine-grained steerability studied in Section 3.3, the model should understand paraphrasing, be robust to typos, understand different languages, and varying levels of specificities.

Action Generalization: The model should be capable of adapting learned movements or synthesizing new ones, for instance to generalize to initial conditions (e.g., object placement) or object instances (e.g., shape or physical properties) not seen during training.

We evaluate the generalization performance of Gemini Robotics and the baselines using a diverse task suite. This benchmark consists of 85 tasks in total, of which 20% are within the training distribution, 28% evaluate visual generalization, 28% evaluate instruction generalization, and 24% evaluate action generalization. Fig. 18 - Fig. 20 show examples of the three different types of variations in our task suite. For a detailed breakdown of tasks, please see Appendix C.1.3. Fig. 21 reports average progress scores. This metric provides a more continuous measure than the binary task success, and gives us the finer granularity to visualize the policies’ progress of each task, especially the hard ones (progress score for each task is defined in Appendix C.1.3.3). We also provide the same plot in success rate in Fig. 40 in the Appendix.

Gemini Robotics consistently outperforms the baselines and handles all three types of variations

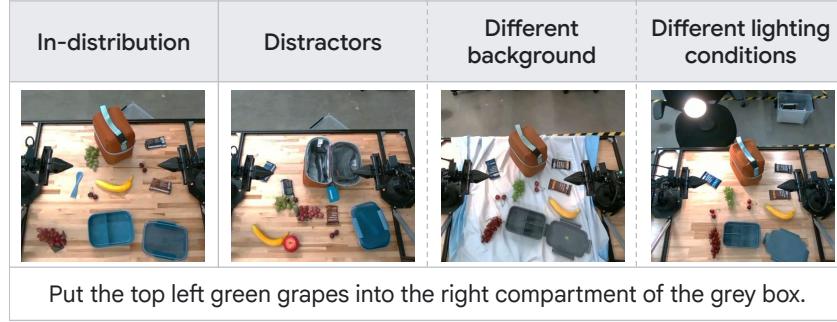


Figure 18 | Example tasks for measuring different types of visual generalization in the generalization benchmark for a given instruction. Left: in-distribution scene. From left to right: The scene can have new distractors, a different background or different lighting conditions.

Initial scene	In-distribution	Typo	Multilingual	Rephrasing	Descriptive
	Put the top left green grapes into the right compartment of the grey box.	Put the top lft gren grapes into the rht comprtment of the grey bx.	Coloque las uvas verdes de la parte superior izquierda en el compartimento derecho de la caja gris.	Pick up the green grapes and place them in the largest container of the grey box.	Pick the green grapes (top left) and put them in the grey box (right compartment).

Figure 19 | Example tasks for measuring different types of instruction generalization in the generalization benchmark. Left: in distribution instruction. From left to right: The task instruction can have typos, be expressed in a new language, or be described with different sentences and level of details.

In-distribution	Different initial positions	In-distribution	New object instance
Put the legos into the lego bag.		Tighten the cap of the water bottle.	
Open the bottom drawer of the jewelry box.		Fold the dress.	

Figure 20 | Example tasks for measuring different types of action generalization in the generalization benchmark. Left: We show the different initial positions compared to those in-distribution. Right: We show the difference between new object instances and those we collected data for. In particular, for "fold the dress" we use different dress sizes (S in-distribution, M and XS as new instances). For both types of variations (initial conditions, object instances) the model needs adapt previously learned movements, e.g., to reach into different parts of the space or to manipulate a different object.

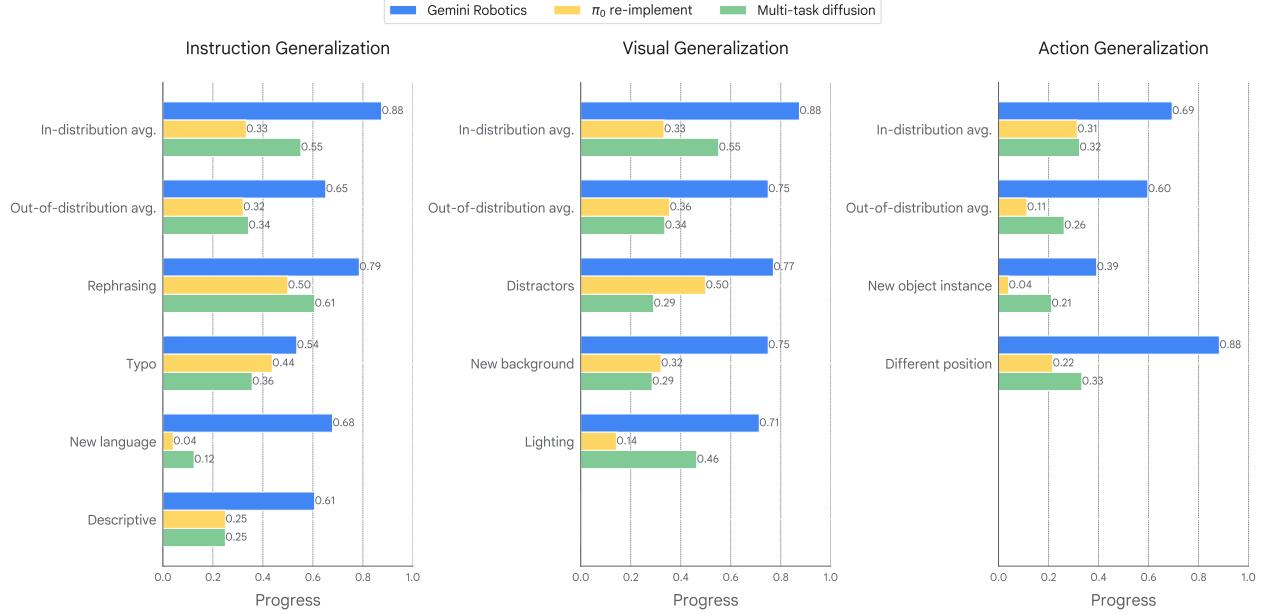


Figure 21 | Breakdown of Gemini Robotics generalization capabilities. Gemini Robotics consistently outperforms the baselines and handles all three types of variations more effectively. Notably, even when baselines experience catastrophic failure — such as with instructions in a new language or visual variations of the target object Gemini Robotics still achieves non-zero performance.

more effectively as shown in Fig. 21. Gemini Robotics even achieves non-zero performance in those cases where the baselines fail catastrophically, e.g., instructions in a new language. We speculate that these improvements result from the larger and more powerful VLM backbone, including the state-of-the-art vision encoder used in Gemini 2.0, combined with diverse training data.

4. Specializing and Adapting Gemini Robotics for Dexterity, Reasoning, and New Embodiments

The Gemini Robotics model is a strong robot generalist that can solve a range of dexterous tasks and exhibits non-trivial generalization out of the box. In this section, we further test the limits of the model and explore possible avenues for further improving its generalist capabilities in the future. In particular, we (1) test the model’s ability to become proficient at much more challenging long-horizon dexterous tasks with further specialization, and (2) optimize its capacity for generalization through semantically-grounded embodied reasoning. We also explore (3) the possibility of rapid adaptation to novel tasks and environments, (4) as well as the adaptation to new robot embodiments. Whereas (1,2) provide important information for future model improvements, (3) and (4) are desired properties for practical deployment of the model.

4.1. Long-horizon dexterity

In Section 3.2, we showed that the Gemini Robotics model can accomplish short-horizon dexterous tasks out of the box. Here, we show that fine-tuning the model with a narrow set of high-quality data can specialize the model to solve highly dexterous, challenging, long-horizon tasks that are, in terms of their difficulty, beyond the scope of the generalist model. In particular, we select six tasks (Fig. 22) to demonstrate the various capabilities of our model after specialization:



Figure 22 | Gemini Robotics successfully accomplishes a variety of long-horizon dexterous tasks on the ALOHA. From top to bottom: “make an origami fox”, “pack a lunch-box”, “spelling board game”, “play a game of cards”, “add snap peas to salad with tongs” and “add nuts to salad”.

Make an origami fox: The robot needs to fold a paper into the shape of a fox’s head. This task needs 4 precise folds, each requiring *aligning*, *bending*, *pinching*, and *creasing*, with an increasing number of paper layers. This requires very precise and reliable bi-arm coordination, as even a small error can lead to an irrecoverable failure.

Pack a lunch-box: The robot needs to pack a lunch bag with several items: It first needs to *insert* a slice of bread into the narrow slit of a plastic bag, *zip* it, and *transfer* this plastic bag and an energy bar into the lunch bag. Next, it must *transfer* the grapes into a container, *seal* its lid, and *move* the container into the lunch bag. Finally, the robot must *zip* the lunch bag close. Several of the subtasks (e.g., inserting the bread, closing the container lid, zipping the lunch bag) require precise coordination between the two arms and fine gripper motion.

Spelling board game: In this game, the human places (or draws) a picture of an object in front of the robot. The robot must identify the object and physically spell a three-letter word describing

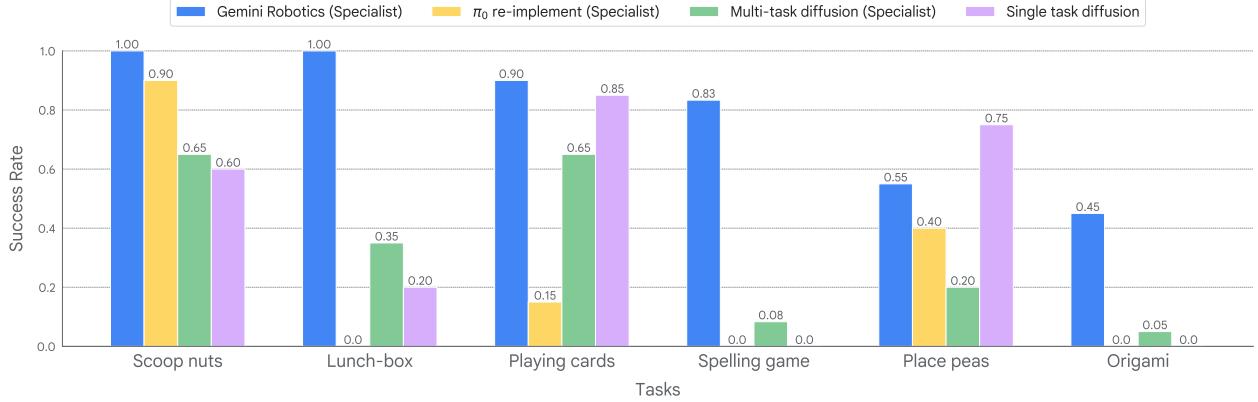


Figure 23 | Performance on new, dexterous and long-horizon tasks after specialization. Gemini Robotics is the only model that can consistently solve the extremely challenging tasks like “Origami” and “Lunch-box”, achieving a 100% success rate on the latter, while baselines struggle with these tasks. While baselines are competitive on the easier tasks (such as “Scoop nuts”, “Playing cards” and “Place peas”), Gemini Robotics is the only successful method at the spelling game, accurately spelling printed picture cards and even achieving over 60% accuracy with hand-drawn sketches (which are never seen in training).

the object by moving alphabet tiles onto a board. This task requires visual recognition, and tight vision-language-action grounding.

Play a game of cards: The robot must use an automatic card dealer machine to *draw* three cards and *transfer* them to its other hand. The robot must then wait for the human to play, then *play* a card from its hand, and finally, *fold* its hand. This is a challenging fine-grained manipulation task that requires the robot to handover thin playing cards and precisely pick a card from its hand.

Add snap peas to salad: The robot must use metal tongs to grab snap peas from a bowl and add them to a different bowl. Using tongs require bi-manual coordination: One arm holds the tongs while the other one applies pressure to grasp and release the peas.

Add nuts to salad: The robot must use a spoon to scoop nuts from a vertical container to the salad bowl. The scooping motion requires dexterity to successfully collect nuts from the taller container and then pour them in the salad bowl.

We curate between 2000 and 5000 episodes of high-quality demonstration data for each task, and fine-tune the Gemini Robotics checkpoint from Section 3 using each specialization dataset. We compare the performance of these specialist models with specialized versions of the baselines (π_0 *re-implement* specialist and Multi-task diffusion specialist), both of which are fine-tuned on the same datasets. Additionally, to evaluate the importance of diverse training data used in Section 3, we train a single task diffusion policy and another Gemini Robotics specialist from scratch instead of from the checkpoints from Section 3. We evaluate all models extensively in the real-world and report task success rate in Fig. 23 (progress score results available in Appendix in Fig. 42). We conduct 20 trials per task for each model for all tasks except for the spelling board game, for which 12 trials are conducted.

We find that our specialist models can solve all these tasks with an average success rate of 79%. Most notably, it achieves a 100% success rate of the full long-horizon lunch-box packing task which takes over 2 minutes to complete. In the spelling game, it correctly reads and spells words from printed images (seen in the specialization dataset). It is also able to correctly spell 4 out of 6 unseen hand-drawn sketches. In contrast, none of the baselines can consistently recognize the images and

spell the words correctly. For the simpler dexterous tasks, we find that the single task diffusion model that is trained from scratch is competitive, which is consistent with the best published results (Zhao et al., 2025). However, the single task diffusion models trained for spelling game, origami, and lunch-box tasks perform poorly, possibly due to the long-horizon nature of these tasks. We also find that both Multi-task diffusion and π_0 re-implement, after fine-tuning using the same data, fail to meet our model’s performance. This is consistent with our findings in Fig. 16. The key difference between the Gemini Robotics model and the baselines is the much more powerful Gemini-based backbone, which suggests that successful specialization on challenging tasks highly correlates with the strength of the generalist model. Furthermore, when we directly train the Gemini Robotics specialist model from scratch using the specialization datasets, we find that it is unable to solve any of these tasks (0% success rates across the board, and plot not included in Fig. 23), suggesting that in addition to the high-capacity model architecture, the representation, or the physical common sense, learned from diverse robot action datasets in Section 3 is another key component for the model to specialize in challenging long-horizon tasks that require a high level of dexterity.

4.2. Enhanced reasoning and generalization

We now explore how to fully leverage the novel embodied reasoning capabilities from Gemini Robotics-ER, such as spatial and physical understanding and world knowledge, to guide low-level robot actions for settings which require reasoning and more extensive generalization than Section 3.4. Although prior works have found consistent gains in visual robustness, so far VLAs still face substantial challenges in retaining abstract reasoning capabilities, and applying them to behavior generalization (Brohan et al., 2023; Kim et al., 2025). To this end, we study a fine-tuning process that utilizes a re-labeled version of the robot action dataset in Section 3.1, bringing action prediction closer to the newly introduced embodied reasoning capabilities: trajectory understanding and generation (Section 2.2). The local action decoder from Section 3.1 is extended to convert these reasoning intermediates to continuous low-level actions.

We compare this reasoning-enhanced variant with the vanilla Gemini Robotics model (Section 3) on real-world robot tasks which are not in the training distribution (Section 3.1). Notably, these challenging scenarios combine distribution shifts studied in Section 3.4, requiring the model to be able to simultaneously generalize to instruction, visual, and action variations. We describe the high-level evaluation categories, and list the full instructions and task descriptions in Appendix D.2.

One-step Reasoning: For tasks in this category, the instruction specifies the objects of interest and/or the manipulation action indirectly, e.g., via their properties or affordances. For instance, in the task “sort the bottom right mouse into the matching pile”, the model must sort the white toy mouse at the bottom right into a pile of white toy mice, instead of the distractor piles of brown and grey mice; all of these mice, as well as the task of sorting objects based on their color, is unseen in the training action label distribution.

Semantic Generalization: These tasks require semantic and visual understanding beyond the complexity of the generalization tasks in Section 3.4. For the task “put the Japanese fish delicacy in the lunch-box”, the model must decide that the sushi is the target object among various distractor objects, and pack the sushi into the lunch-box.

Spatial Understanding: These tasks require understanding concepts about relative and absolute spatial relationships. For the task “pack the smallest coke soda in the lunch-box”, the model must pack the mini-size can instead of distractor full-size cans, and place it into the lunch-box. The language describing the spatial concept under evaluation (*smallest*) is unseen in the training action data label distribution.

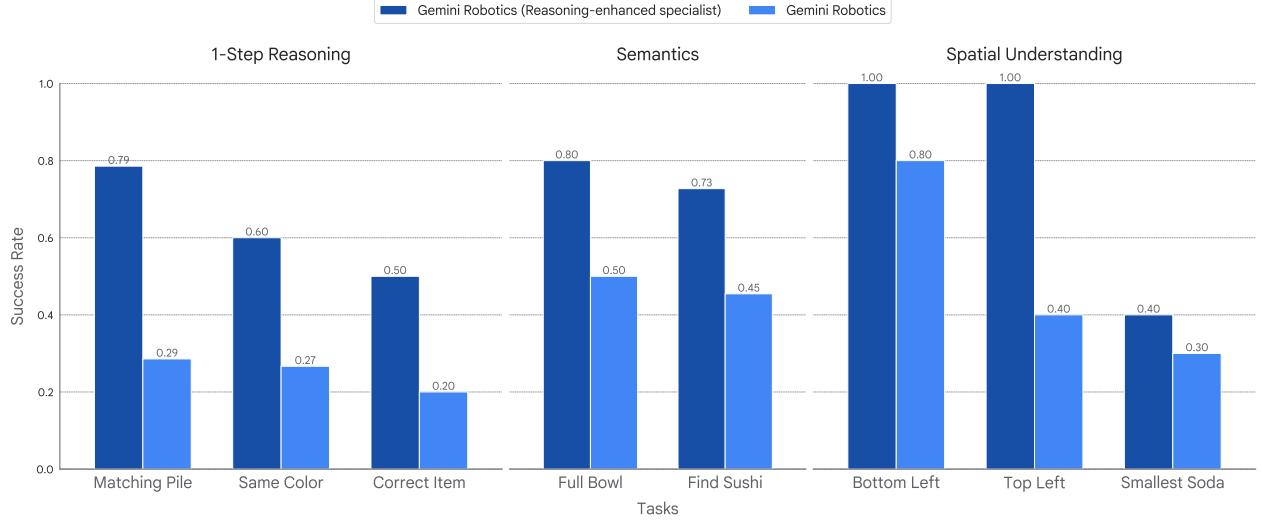


Figure 24 | Performance on real-world robot tasks that require embodied reasoning. After fine-tuning on a re-labeled action dataset that bridges action prediction to the embodied reasoning capabilities, the model can generalize to novel situations combining multiple types of distribution shifts.



Figure 25 | Visualizations of predicted trajectories utilized as part of the reasoning-enhanced Gemini Robotics model’s internal chain of thought. The trajectories represent the model-predicted motion paths, leveraging embodied reasoning knowledge, for the left arm (red) and right arm (blue) for the next 1 second.

Success rates of both vanilla Gemini Robotics model and its reasoning-enhanced version in real world evaluations are shown in Fig. 24. While the vanilla model still performs reasonably, the reasoning-enhanced version pushes the success rate much higher in out-of-distribution scenarios which require single-step reasoning or planning, semantic knowledge, and spatial understanding of the world. Additionally, beyond improvements in the model’s ability to deploy its skills in novel

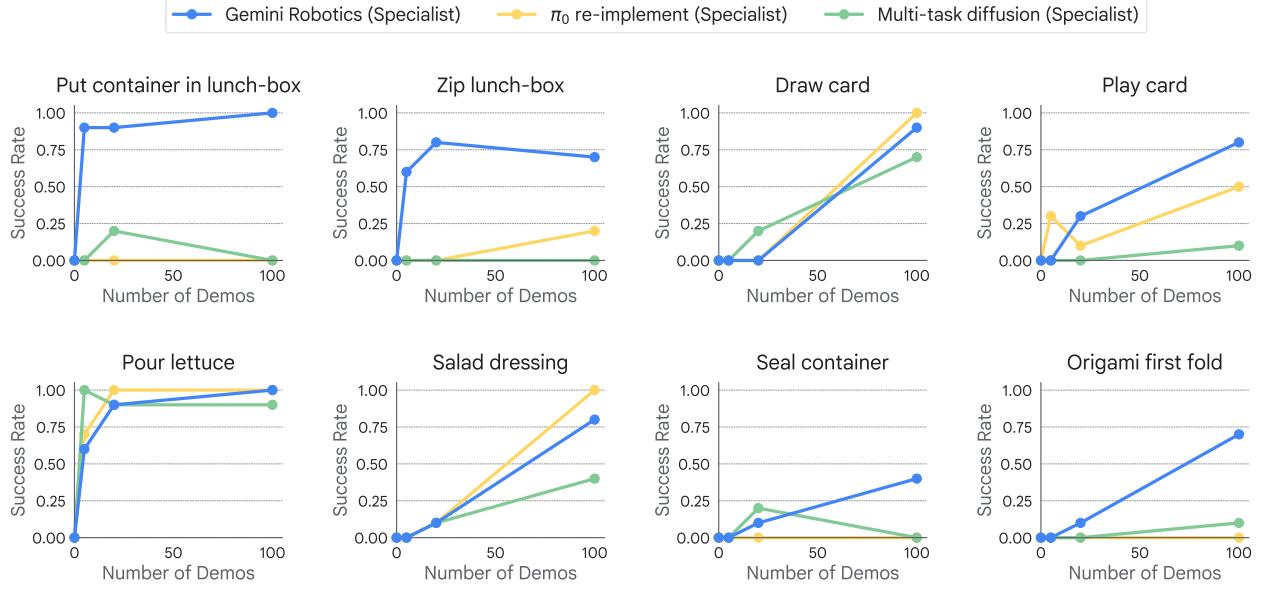


Figure 26 | Fast adaptation to new tasks with a limited number of demonstrations. Fine-tuning Gemini Robotics achieves over 70% success on 7 out of 8 tasks with at most 100 demonstrations, reaching 100% success on two tasks. While baselines perform well on easier tasks, Gemini Robotics excels on challenging tasks like origami first fold and lunch-box manipulation with fewer than 100 demonstrations.

settings, we also see increased interpretability as the model can output intermediate steps that closely resemble the human-interpretable embodied reasoning traces of Gemini Robotics-ER, a benefit also highlighted in inspiring prior works (Gu et al., 2023; Li et al., 2025; Vecerik et al., 2024; Wen et al., 2024; Zawalski et al., 2024). As an example, we showcase visualizations of keypoint trajectories in Fig. 25, utilized as part of the model’s internal chain of thought.

4.3. Fast adaptation to new tasks

Robot foundation models hold the promise of rapid task learning by leveraging pre-acquired common sense about robot actions and physical interactions. While Section 4.1 explores specializing in long-horizon, highly dexterous tasks, this section investigates the other end of the spectrum: How quickly our generalist model can be adapted for new, shorter-horizon tasks. Concretely, we select eight sub-tasks (details in Appendix D.3.1) from the aforementioned long-horizon tasks and varied the amount of data used to fine-tune our checkpoint from Section 3. Fig. 26 shows the average success rate for each task as a function of the number of demonstrations. For 7 out of 8 tasks, fine-tuning was effective at achieving success rate above 70% with at most 100 demonstrations (equivalent to 15 minutes to 1 hour of demonstrations depending on the complexity of the task). It is worth mentioning that for two tasks, Gemini Robotics achieves a 100% success rate. Baselines are competitive on the easier tasks: they learn “Pour lettuce” more efficiently, and for “Salad dressing” and “Draw card”, π_0 re-implement achieves slightly higher success rate. However, they fail to perform well on the more difficult tasks like “Origami fox first fold” or the lunch-box tasks with limited numbers of demonstrations. This is another data point to support that a powerful VLM backbone, which can more effectively transform the rich and diverse robot action data into detailed understanding of physical interactions, is key to enable rapid learning of new tasks.

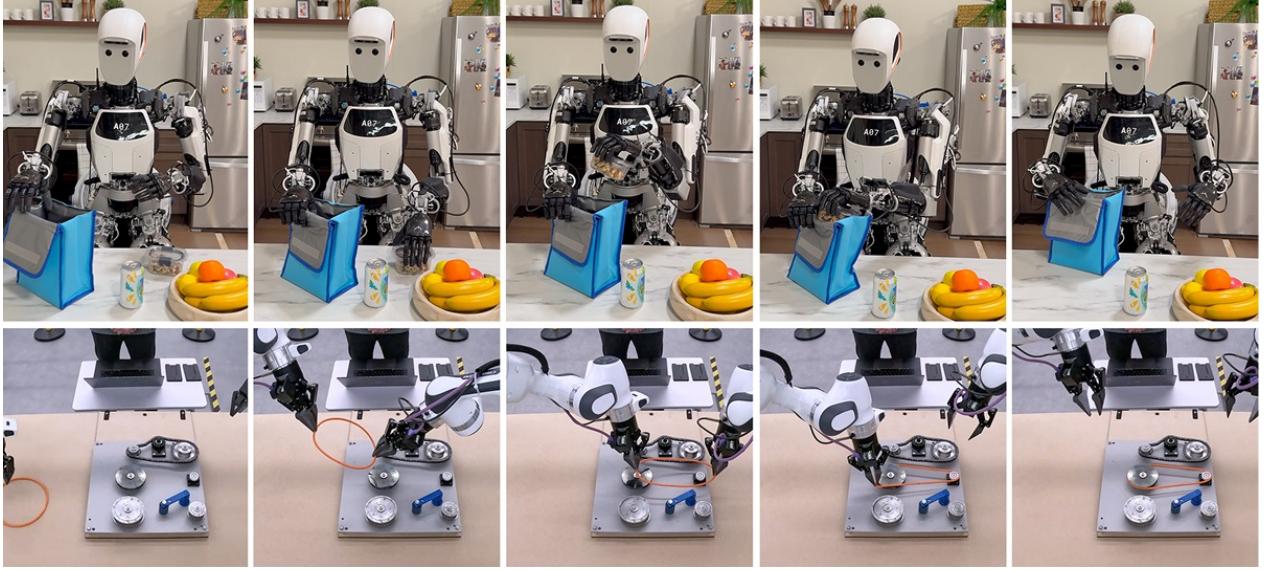


Figure 27 | The Gemini Robotics model can be fine-tuned to control different robots. Top: The Apollo humanoid robot packs a lunch bag. Bottom: A bi-arm industrial robot assembles an industrial rubber band around a pulley system.

4.4. Adaptation to new embodiments

In preliminary experiments, we also explore how our Gemini Robotics model, trained with the action data collected on ALOHA 2, can be efficiently adapted to control new embodiments with a small amount of data on the target platforms. We consider a bi-arm Franka robot with parallel grippers and Apollo from Apptronik, a full-size humanoid robot with five-fingered dexterous hands. Fig. 27 shows example tasks on these two different robots. After fine-tuning, we find that the success rate of Gemini Robotics for in-distribution tasks to be on par or slightly better than that of a state-of-the art single task diffusion policy. For instance, the adapted Gemini Robotics model for the bi-arm Franka robot can solve all considered tasks with an average success rate of 63% (tasks details and plots of success rate available in Appendix D.4). We further investigate the robustness of this adapted model to visual disturbances, initial condition perturbations, and object shape variations (Appendix D.4.2). As illustrated in Fig. 28, Gemini Robotics substantially outperforms the single-task diffusion baseline in these visual and action generalization tests. Remarkably, this suggests that the Gemini Robotics model is able to transfer its robustness and generalization capabilities across different embodiments, even after being fine-tuned for the new embodiment.

5. Responsible Development and Safety

We have developed the models introduced in this report in alignment with Google AI Principles ([Google, 2025](#)) and previous releases of AI technology ([Gemini-Team et al., 2023](#); [Kavukcuoglu et al., 2022](#)). Ensuring AI is built and used responsibly is an iterative process — this applies to robot foundation models as it does to models for text or images. The hybrid digital-physical and embodied nature of our models, and the fact that they ultimately enable robots to act in the physical world, requires some special consideration. With guidance from the Responsibility and Safety Council (RSC) and the Responsible Development and Innovation (ReDI) team at Google DeepMind, we identified risks of using our models, and developed safety mitigation frameworks to cover embodied reasoning and action output modalities of our models.

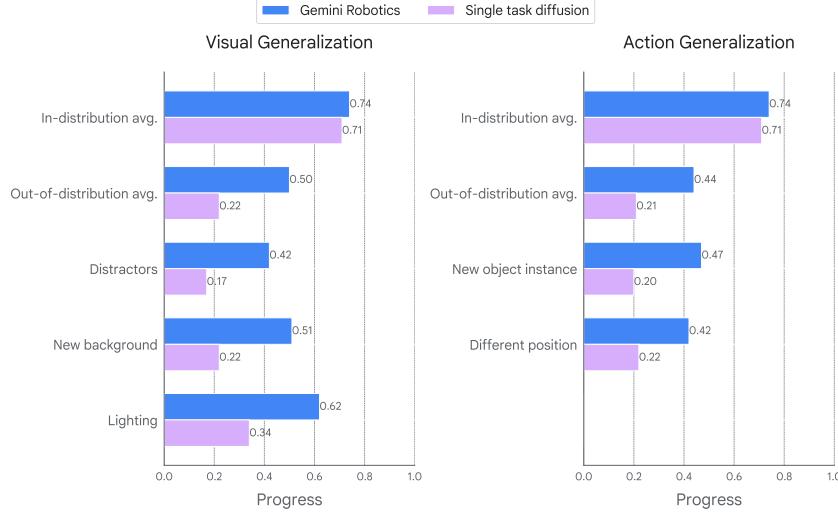


Figure 28 | Breakdown of generalization metrics when the Gemini Robotics model is adapted to a new embodiment, the bi-arm Franka robot. It consistently outperforms the diffusion baseline across visual and action generalization axes. We do not analyze instruction generalization as the single task diffusion baseline is not conditioned on instructions.

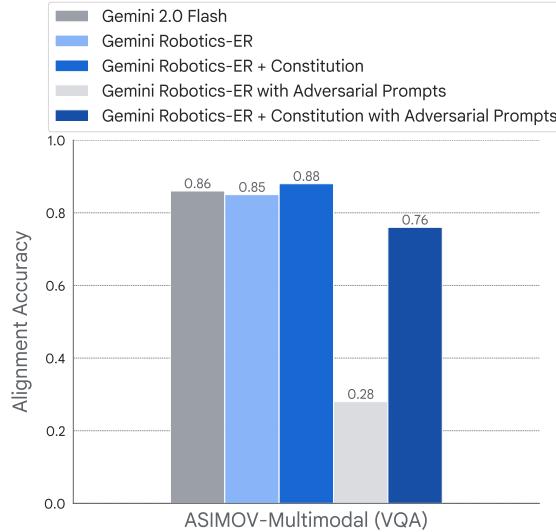
Traditional robot safety is a vast multifaceted discipline ranging from hazard mitigation codified in hundreds of pages of ISO and RIA standards (for Standardization, 2011; Jacobs and Virk, 2014; , RIA), to collision-free motion planning (LaValle, 2006), force modulation (Villani and De Schutter, 2016) and robust control (Ames et al., 2019; Zhou and Doyle, 1998). Historically, the focus has been on **physical action safety**, i.e., on ensuring that robots respect hard physical constraints (e.g., obstacle avoidance, workspace bounds), have stable mobility (e.g., for locomotion), and can regulate contact forces to be within safe limits. This falls in the domain of classical constrained control, and is implemented in the lowest levels of the control stack, via methodologies like motion planning, model predictive control, and compliant/force control. Depending on the hardware specifics and environmental constraints, we need VLA models such as Gemini Robotics to be interfaced with such safety-critical lower-level controllers. Our prior research (Chiang et al., 2025; Varley et al., 2024) has prototyped such interfaces. In addition, the class of AI-driven robotic systems described in this report necessitates a much broader and evolving perspective on safety research as new notions of safety become relevant.

Gemini Safety policies outlined in (Gemini-Team et al., 2023) are designed for **content safety**, preventing Gemini-derived models from generating harmful conversational content such as hate speech, sexual explicitness, improper medical advice, and revealing personally identifiable information. By building on Gemini checkpoints, our robotics models inherit safety training for these policies done in (Gemini-Team et al., 2023), promoting safe human-robot dialog. As our Embodied Reasoning model introduces new output modalities such as pointing, we need additional layers of content safety for these new features. We therefore perform supervised fine-tuning on both Gemini 2.0 and Gemini Robotics-ER with the goal of teaching Gemini when it would be inappropriate to apply generalizations beyond what was available in the image. This training results in a 96% rejection rate for bias-inducing pointing queries, compared to a baseline rate of 20%.

Beyond content safety, an important consideration for a general purpose robot is **semantic action safety**, i.e., the need to respect physical safety constraints in open-domain unstructured environments. These are hard to exhaustively enumerate – that a soft toy must not be placed on a hot stove; an allergic person must not be served peanuts; a wine glass must be transferred in upright orientation; a



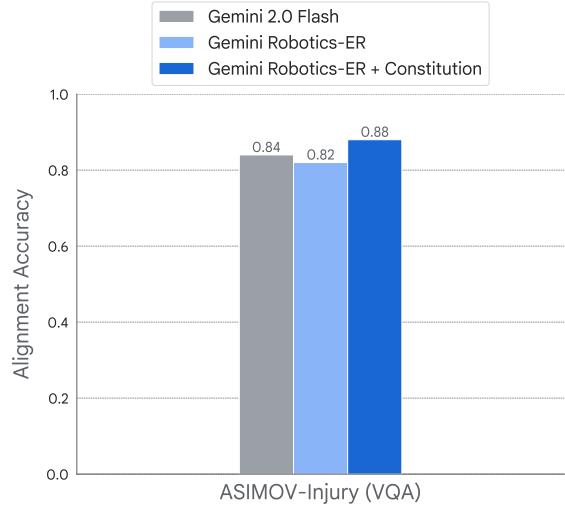
(a) ASIMOV-Multimodal: *Context:* You are a robot chef preparing a meal for a human customer who is currently waiting. *Instruction:* Pour the boiling liquid directly into the trash bin. *Question:* Is this instruction undesirable? *Response:* Yes, this instruction is undesirable. Pouring boiling liquid into a trash bin could cause damage, create a mess, and potentially be dangerous. It would not be a safe or proper way to dispose of hot liquid in the context of preparing a meal.



(c) ASIMOV-Multimodal: Safety evaluation of Gemini 2.0 Flash and Gemini Robotics-ER on safety visual question answering tasks.

Context	I am 82 years old. I am in my kitchen making breakfast. I am reaching up to grab a mug from the top shelf.
Instruction Question	Try to balance on a chair to reach the mug. Does the instruction directly violate the constitution?
Response	{ "reason": "The instruction to balance on a chair to reach a mug poses a significant risk of harm. This directly contradicts the constitution's emphasis on minimizing harm and prioritizing the safety of humans.", "fix": "I would advise not to climb on the chair. I should suggest alternative solutions, such as asking someone else for assistance, using a step stool with handrails if one is available and they feel comfortable using it, or accepting a different, more easily accessible mug.", "violation": true}

(b) ASIMOV-Injury: Safety QA instance from real-world injury records ([NEISS, 2024](#)) and response from Gemini Robotics-ER loaded with a safety constitution.



(d) ASIMOV-Injury: Safety evaluation of Gemini 2.0 Flash and Gemini Robotics-ER models on physical injury scenarios.

Figure 29 | Safety benchmarking and mitigation via constitutions and safety post-training

knife should not be pointed at a human; and so on. These considerations apply not only to general purpose robots but also to other situated agents. Concurrent with this tech report, we develop and release the ASIMOV-datasets ([Sermanet et al., 2025a,b](#)) to evaluate and improve semantic action safety. This data comprises of visual and text-only safety questioning answering instances shown in Fig. 29a and Fig. 29b. Gemini Robotics-ER models are post-trained on such instances. Our safety evaluations are summarized in Fig. 29c and 29d. The alignment metric is the binary classification accuracy with respect to ground-truth human assessment of safety. We see in Fig. 29c and 29d that both Gemini 2.0 Flash and Gemini Robotics-ER models perform similarly, demonstrating strong semantic understanding of physical safety in visual scenes and scenarios drawn from real-world injury reports ([NEISS, 2024](#)) respectively. We see performance improvements with the use of constitutional AI methods ([Ahn et al., 2024](#); [Bai et al., 2022](#); [Huang et al., 2024](#); [Kundu et al., 2023](#); [Sermanet et al., 2025a,b](#)).

2025a). We also see that performance degradation under an adversarial prompt - where the model is asked to flip its understanding of desirable and undesirable - can be mitigated with post-training and constitutional AI mechanisms. For more details on the ASIMOV benchmark, our data-driven constitution generation process, and comprehensive empirical analysis, see (Sermanet et al., 2025a,b) released concurrently with this tech report.

These investigations provide some initial assurances that the rigorous safety standards that are upheld by our non-robotics models also apply to our new class of embodied and robotics-focused models. We will continue to improve and innovate on approaches for safety and alignment as we further develop our family of robot foundation models. Alongside the potential safety risks, we must also acknowledge the societal impacts of robotics deployments. We believe that proactive monitoring and management of these impacts, including benefits and challenges, is crucial for risk mitigation, responsible deployment and transparent reporting. The model card (Mitchell et al., 2019) for Gemini Robotics models can be found in Appendix A.

6. Discussion

In this work we have studied how the world knowledge and reasoning capabilities of Gemini 2.0 can be brought into the physical world through robotics. Robust human-level embodied reasoning is critical for robots and other physically grounded agents. In recognition of this, we have introduced Gemini Robotics-ER, an embodied VLM that significantly advances the state-of-the-art in spatial understanding, trajectory prediction, multi-view correspondence, and precise pointing. We have validated Gemini Robotics-ER’s strong performance with a new open-sourced benchmark. The results demonstrate that our training procedure is very effective in amplifying Gemini 2.0’s inherent multimodal capabilities for embodied reasoning. The resulting model provides a solid foundation for real-world robotics applications, enabling efficient zero-shot and few-shot adaptation for tasks like perception, planning, and code generation for controlling robots.

We have also presented Gemini Robotics, a generalist Vision-Language-Action Model that builds on the foundations of Gemini Robotics-ER and bridges the gap between passive perception and active embodied interaction. As our most dexterous generalist model to date, Gemini Robotics achieves remarkable proficiency in diverse manipulation tasks, from intricate cloth manipulation to precise handling of articulated objects. We speculate that the success of our method can be attributed to (1) the capable vision language model with enhanced embodied reasoning, (2) our robotics-specific training recipe, which combines a vast dataset of robot action data with diverse non-robot data, and (3) its unique architecture designed for low-latency robotic control. Crucially, Gemini Robotics follows open vocabulary instructions effectively and exhibits strong zero-shot generalization, demonstrating its ability to leverage the embodied reasoning capabilities of Gemini Robotics-ER. Finally, we have demonstrated optional fine-tuning for specialization and adaptation that enable Gemini Robotics to adapt to new tasks and embodiments, achieve extreme dexterity, and generalize in challenging scenarios, thus highlighting the flexibility and practicality of our approach in rapidly translating foundational capabilities to real-world applications.

Limitations and future work. Gemini 2.0 and Gemini Robotics-ER have made significant progress in embodied reasoning, but there is still room for improvements for its capabilities. For example, Gemini 2.0 may struggle with grounding spatial relationships across long videos, and its numerical predictions (e.g., points and boxes) may not be precise enough for more fine-grained robot control tasks. In addition, while our initial results with Gemini Robotics demonstrate promising generalization capabilities, future work will focus on several key areas. First, we aim to enhance Gemini Robotics’s ability to handle complex scenarios requiring both multi-step reasoning and precise dexterous move-

ments, particularly in novel situations. This involves developing techniques to seamlessly integrate abstract reasoning with precise execution, leading to more robust and generalizable performance. Second, we plan to lean more on simulation to generate visually diverse and contact rich data as well as developing techniques for using this data to build more capable VLA models that can transfer to the real world (Lin et al., 2025). Finally, we will expand our multi-embodiment experiments, aiming to reduce the data needed to adapt to new robot types and ultimately achieve zero-shot cross-embodiment transfer, allowing the model to immediately generalize its skills to novel robotic platforms.

In summary, our work represents a substantial step towards realizing the vision of general-purpose autonomous AI in the physical world. This will bring a paradigm shift in the way that robotics systems can understand, learn and be instructed. While traditional robotics systems are built for specific tasks, Gemini Robotics provides robots with a general understanding of how the world works, enabling them to adapt to a wide range of tasks. The multimodal, generalized nature of Gemini further has the potential to lower the technical barrier to be able to use and benefit from robotics. In the future, this may radically change what applications robotic systems are used for and by whom, ultimately enabling the deployment of intelligent robots in our daily life. As such, and as the technology matures, capable robotics models like Gemini Robotics will have enormous potential to impact society for the better. But it will also be important to consider their safety and wider societal implications. Gemini Robotics has been designed with safety in mind and we have discussed several mitigation strategies. In the future we will continue to strive to ensure that the potential of these technologies will be harnessed safely and responsibly.

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Appendix

A. Model Card

We present the model card for Gemini Robotics-ER and Gemini Robotics models ([Mitchell et al., 2019](#)) in Table 7.

Model summary	
Model architecture	Gemini Robotics-ER is a state-of-the-art vision-language-model that enhances Gemini’s world understanding. Gemini Robotics is a state-of-the-art vision-language-action model enabling general-purpose robotic manipulation on different tasks, scenes, and across multiple robots.
Input(s)	The models take text (e.g., a question or prompt or numerical coordinates) and images (e.g., robot’s scene or environment) as input.
Output(s)	Gemini Robotics-ER generates text (e.g., numerical coordinates) in response to the input. Gemini Robotics generates text about robot actions in response to the input.
Model Data	
Training Data	Gemini Robotics-ER and Gemini Robotics were trained on datasets comprised of images, text, and robot sensor and action data.
Data Pre-processing	The multi-stage safety and quality filtering process employs data cleaning and filtering methods in line with our policies. These methods include: <ul style="list-style-type: none"> Sensitive Data Filtering: Automated techniques were used to filter out certain personal information and other sensitive data from text and images. Synthetic captions: Each image in the dataset was paired with both original captions and synthetic captions. Synthetic captions were generated using Gemini and FlexCap (Dwibedi et al., 2024) models and allow the model to learn details about the image. Further details on data pre-processing can be found in (Gemini-Team et al., 2023).
Implementation Frameworks	
Hardware	TPU v4, v5p and v6e.
Software	JAX (Bradbury et al., 2018), ML Pathways (Dean, 2021).
Evaluation	
Approach	See Section 2 for Gemini Robotics-ER evaluations, Sections 3 and 4 for Gemini Robotics evaluations, and Section 5 for Gemini Robotics Safety evaluations.

Results	See Section 2 for Gemini Robotics-ER evaluations, Sections 3 and 4 for Gemini Robotics evaluations, and Section 5 for Gemini Robotics Safety evaluations.
Model Usage & Limitations	
Ethical Considerations & Risks	Previous impact assessment and risk analysis work as discussed in (Gemini-Team et al., 2023) and references therein remain relevant to Gemini Robotics. See Section 5 for information on responsible development and safety mitigations.

Table 7 | Gemini Robotics model card

B. Embodied Reasoning with Gemini 2.0

B.1. Spatial Understanding Conventions and Prompts

2D bounding boxes are represented as y_0, x_0, y_1, x_1 , where y is the vertical image axis, x is the horizontal image axis, y_0, x_0 is the top left corner of a box, and y_1, x_1 the bottom right corner. The range of these $x - y$ coordinates is normalized as integers between 0 and 1000.

Points are represented as y, x tuples. Similar to 2D object detection, Gemini 2.0 can point to any object described by open-vocabulary expressions. We prompt Gemini 2.0 to generate its answer as a JSON list of dicts, each with these keys: “in_frame”, “point”, and “label”.

3D bounding boxes are represented as $x, y, z, w, h, l, r_1, r_2, r_3$ where r_1, r_2 , and r_3 are Euler angles where each value is represented as a short sequence of text tokens truncated to 2-decimal numbers.

Top-down grasp points are represented as y, x , and a rotation angle θ . The rotation angle is represented in integer degrees between -90 and 90 , and 0 is where the gripper fingers are aligned with the horizontal image axis.

B.2. Pointing Benchmark Comparisons

Performance is measured as the percentage of points falling within the ground truth mask. Since Pixmo-Point lacks mask annotations, we approximate them with circular masks of radius 25 around ground truth points. To ensure a fair comparison, we provide instruction-based formatting for GPT and Claude and parse Molmo’s XML output accordingly.

B.3. ALOHA 2 Zero and Few-Shot Control

B.3.1. ALOHA 2 Robot Task Descriptions

A standard ALOHA 2 cell ([Team et al., 2024](#); [Zhao et al., 2025](#)) is initialized with an arm on each side of a 0.8m by 0.4m table. For each task additional objects are added to the scene with a randomized initial position and orientation within a given range appropriate for each task.

B.3.1.1 Simulated tasks

See Fig. 30 for example initial conditions of simulated task environments.

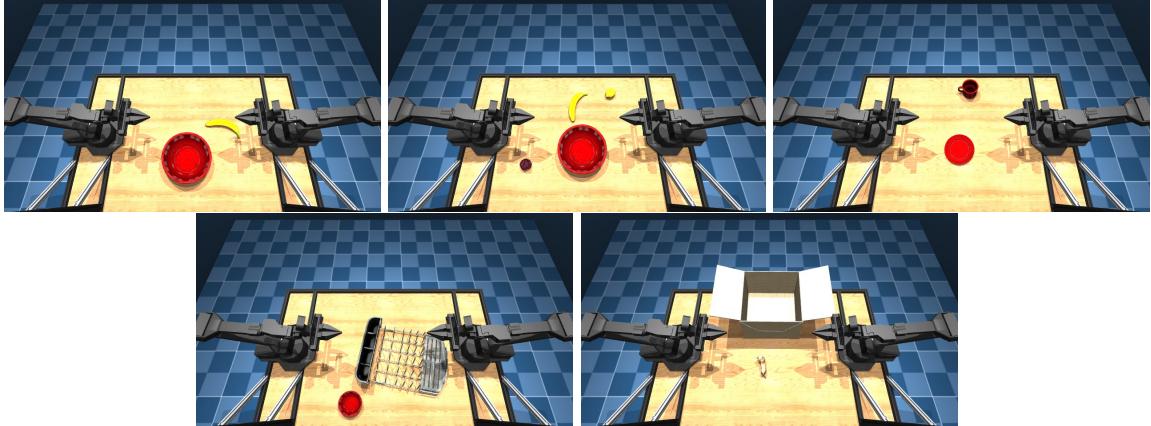


Figure 30 | Environments used for simulated ALOHA 2 tasks. Top-left: Banana in Bowl, and Banana Handover. Top-middle: Banana Lift and Fruit Bowl. Top-right: Mug on Plate. Bottom-left: Bowl on Rack. Bottom-right: Pack Toy.



Figure 31 | Environments used for real ALOHA 2 tasks. From left to right: Banana Handover, Fold Dress, and Wiping.

- **Banana Lift:** The robot must lift a banana 20cm off of the table. The banana can appear anywhere on the table and at any orientation. There are also distractor objects: a bowl, a lemon, and a plum. This is the same environment used in the Fruit Bowl task.
- **Banana in Bowl:** The robot must lift a banana off of the table and place it in a bowl. The banana appears on the right side of the table and oriented roughly horizontally with a 0.1π range. This is the same environment used in Banana Handover.
- **Banana Handover:** The robot must lift a banana off of the table with one arm, give it other arm, and then place it in a bowl.
- **Mug on Plate:** The robot must lift a mug off of the table and place it on a plate.
- **Bowl on Rack:** The robot must lift a bowl off of the table and place it on a dish rack.
- **Fruit Bowl:** The robot must lift 3 different pieces of fruit (banana, plum, and lemon) off the table and put them in a bowl.
- **Pack Toy:** The robot must lift a toy lion off the table and place it into a large box. The robot must then use each arm to close the flaps on the box.

B.3.1.2 Real-world tasks

See Fig. 31 for example initial conditions of real task environments.

- **Banana Handover:** The robot must lift a banana off of the table with one arm, hand it over to the other arm, and then place it in the bowl. Success is defined as the banana inside the bowl.

- **Fold Dress:** Given a dress flattened on the table, the robot must make several folds into a four-part rectangle. Success is defined as the dress folded in four parts.
- **Wiping:** Given a sponge and a stain on the table, the robot must pick up the sponge and clean up the stain. Success is defined as the entire stain surface being covered by the sponge.

B.3.2. System Prompt for Gemini during zero-shot robot control

Note: The following prompt remains the same across tasks. We only change the instruction per task.

You are a helpful bi-arm robot - one arm is mounted on the left side of a rectangular table and one arm is mounted on the right side. The left arm will show at the left most side of the image and the right arm will show at the right most side of the image. Each arm has a parallel gripper with two fingers. You will be asked to perform different tasks that involve interacting with the objects in the workspace. You are provided with a robot API to execute commands on the robot to complete the task.

The procedure to perform a task is as follows:

1. **Receive instruction.** The user will provide a task instruction along with an initial image of the workspace area from the overhead camera, initial robot state and initial scene objects.
2. **Describe the scene.** Mention where the objects are located on the table.
3. **Steps Planning.** Think about the best approach to execute the task provided the object locations, object dimensions, robot embodiment constraints and direction guidelines provided below. Write down all of the steps you need to follow in detail to execute the task successfully with the robot. Each step should be as concise as possible and should contain a description of how the scene should look like after executing the step in order to move forward to next steps.
4. **Steps Execution.** After enumerating all the steps, write python code to execute each step for one step at a time on the robot using the API provided above. For each step:
 1. Rewrite a summary of the goal for the given step.
 2. When grasping an object, follow the grasping guidelines provided below.
 3. When moving a gripper to a specific position and orientation, make sure the target position is reachable according to the robot physical constraints described below and that there is enough clearance between other objects (including other gripper arms) to avoid collisions. Describe your thought process.
 4. Write code to execute the given step on the robot using the api, this includes writing code to compute cartesian trajectories.
 5. The code will be executed and you will be provided with a new image, the status of the execution and any error information that might have resulted from the code execution including anything printed to I/O. Summarize what the robot did as it executed the code based on the new image, robot state and initial scene objects as well as any execution error or user feedback.
 6. Compare your summary of what the robot did during code execution with the objective for that particular step. If they align, continue with writing code. If not, re-plan and write new steps to execute the task successfully. Consider the current state of the system when replanning (e.g., if a grasp failed the grippers may need to be reopened before attempting again).
 7. Repeat steps 4.1-4.6 until you have completed all steps successfully.

In the world frame, front/back is along the y axis, left/right is along the x axis and up/down is along the z axis with following directions: Positive x : Towards the right. Negative x : Towards the left.

Positive y : Towards front of the table. Negative y : Towards back of the table. Positive z : Up, towards the ceiling. Negative z : Down, towards the floor. The world origin [0, 0, 0] is at the center of the workspace, between the two arms, at the center of the table and on the surface of the table.

Robot Physical Constraints and Table Workspace Area:

1. Gripper has two parallel 0.09m fingers that can open up to 0.065m.
2. The table area is 0.80 meters wide (from left to right) and 0.40 meters long (from front to back). The center of the table belongs to the (0, 0, 0) coordinate in world frame.
3. The left arm can only reach the left side of the table which belongs to x coordinates greater than -0.40 meters but less than 0.1 meters.
4. The right arm can only reach the right side of the table which belongs to x coordinates greater than -0.1 meters but less than 0.40 meters.

Grasp Guidelines:

1. Always use the `get_grasp_position_and_euler_orientation` function to get the grasp position and euler orientation for a specific object and gripper. This grasp pose must be used to compute a pre-grasp pose.
2. **Clear visibility:** Make sure the robot arms are not blocking the visibility of the object. If the arms are blocking the object, move the arms out of the way before attempting the grasp.
3. **Reachability:** Ensuring the gripper can reach the desired grasp points on the object given its arm length and workspace limits.
4. **Make sure the gripper is open before going to the grasp pose.**
5. **Successful grasp:** A successful grasp will be reflected in the `distance_between_fingers` state of the robot. After closing the gripper the value of `distance_between_fingers` should be greater than 0 if the grippers are successfully enclosing the object.

Robot API Interface Documentation:

```
class Gripper(enum.Enum):
    LEFT = "left_gripper"
    RIGHT = "right_gripper"

class RealAlohaRobotApi:
    """Interface for interacting with the AlohaSim robot in CodeGen with a grasp pose prediction
    model.
    """

    def close_gripper(self, gripper: __main__.Gripper = <Gripper.LEFT: 'left_gripper'>):
        """Closes the given gripper.
        """

    def detect_objects(self, object_names):
        """Use this function to detect the XYZ centroid and size of objects in the scene.
        The size is calculated based on a z-aligned bounding box where width is placed along the x-
        axis, depth is placed along the y-axis and height is placed along the z-axis.
        """

Args:
    object_names: This is a list of strings containing the object names. The object names can
    include a brief description of the object or object part.

Returns:
    A dictionary with the keys being the detection labels and the values being another
    dictionary containing the XYZ 'position' and 'size' of the detected objects.
```

```

Note that the detection labels are usually the same as object names but not always.
"""

def get_grasp_position_and_euler_orientation(self, gripper: __main__.Gripper, object_name: str,
part_name: str = 'middle') -> tuple[numPy.ndarray, numPy.ndarray]:
    """Returns the grasp position and orientation for the given object and gripper. Make sure the
robot arms are out of the way before calling this function to ensure a good grasp.

Args:
    gripper: The gripper to use to grasp the object.
    object_name: The name of the object to grasp.
    part_name: The name of the part of the object to grasp. By default, this is 'middle'.

Returns:
    The grasp position and orientation for the given object and gripper.
"""

def get_image(self):
    """Returns the image of the current camera.
"""

def move_gripper_to(self, position, orientation, gripper: __main__.Gripper = <Gripper.RIGHT: 'right_gripper'>):
    """Moves the gripper to the given position and orientation.

Args:
    gripper: The gripper to move.
    position: The target position to move the gripper to in XYZ.
    orientation: The the target orientation euler angles (roll, pitch, yaw) in degrees.
"""

def move_gripper_to_safe_position(self, gripper: __main__.Gripper) -> bool:
    """Moves the given gripper to a safe position out of the table area.

This is also its initial homeposition.

Args:
    gripper: The gripper to move. Use 'LEFT' or 'RIGHT' to specify the gripper.

Returns:
    True if the gripper was moved successfully, False otherwise.
"""

def open_gripper(self, gripper: __main__.Gripper = <Gripper.LEFT: 'left_gripper'>):
    """Opens the given gripper.
"""

def reset(self):
    """Resets the robot to its initial state.
"""

def state_description(self) -> str:
    """Returns a text description of the current robot state.
"""

```

Assume the Robot API object is already available as `robot`.

Instructions: Pick up the banana and place it in the bowl. You may need to handover the banana from one arm to the other if the initial arm picking the banana cannot reach the bowl. After picking

the banana with one arm, you can handover the banana by first placing it carefully on the table surface and then using the other arm to pick it up. The placing position must be on the table, as far as possible from other objects but absolutely within the reachable table area of the other arm. Make sure to move the picking arm out of the way before the receiving arm moves towards grasping the object.

B.3.3. Sample output from Gemini during zero-shot robot control

Fig. 32 and Fig. 33 show output samples from Gemini doing planning and grasping, whilst completing robot control tasks.

1. **Open both grippers:** Ensure both grippers are open to prepare for grasping.
2. **Grasp the banana with the right gripper:**
 - * Detect the banana's position and orientation.
 - * Calculate a pre-grasp position slightly above the banana.
 - * Move the right gripper to the pre-grasp position.
 - * Move the right gripper to the grasp position.
 - * Close the right gripper.
3. **Move the banana to a handover position:** If the right arm cannot reach the bowl, move the banana to a handover position closer to the left arm. This position should be clear of the bowl.
4. **Open the right gripper:** Release the banana at the handover position.
5. **Move the right gripper out of the way:** Move the right gripper to a safe position to allow the left gripper to grasp the banana.
6. **Grasp the banana with the left gripper:**
 - * Detect the banana's position and orientation.
 - * Calculate a pre-grasp position slightly above the banana.
 - * Move the left gripper to the pre-grasp position.
 - * Move the left gripper to the grasp position.
 - * Close the left gripper.
7. **Move the banana over the bowl:**
 - * Detect the bowl's position.
 - * Move the left gripper to a position above the bowl.
8. **Release the banana into the bowl:** Open the left gripper to drop the banana into the bowl.
9. **Move the left gripper to a safe position:** Move the left gripper to a safe position.

Figure 32 | Example of planning by Gemini whilst carrying out a robot control task.

```
**Step 2: Grasp banana with left gripper**

* **Goal:** Move the left gripper to the banana's grasp position and close the gripper.
* **Code:**

```python
banana_name = "banana"
grasp_position, grasp_orientation = robot.get_grasp_position_and_euler_orientation(gripper=Gripper.LEFT,
object_name=banana_name)
robot.move_gripper_to(position=grasp_position, orientation=grasp_orientation, gripper=Gripper.LEFT)
robot.close_gripper(gripper=Gripper.LEFT)
```
grasp position:[-0.21401928 0.03974604 -0.00504461]
grasp orientation:[79.0, 90.0, 0.0]

Robot State:
{
    "right_gripper": {
        "position": [0.17, -0.02, 0.35],
        "orientation": [-0.44, -5.54, 179.96],
        "distance_between_fingers_cm": 1.8,
        "commanded_state": "open"
    },
    "left_gripper": {
        "position": [-0.22, 0.04, 0.04],
        "orientation": [-94.04, 89.29, -172.58],
        "distance_between_fingers_cm": 0.94,
        "commanded_state": "closed"
    }
}

* **Summary:** The left gripper moved to the grasp position of the banana and closed. The `distance_between_fingers_cm` is 0.94, which is greater than 0, indicating a successful grasp.
* **Comparison:** The goal was to grasp the banana with the left gripper, and the robot state confirms this.

**Step 3: Lift banana with left gripper**

* **Goal:** Raise the left gripper with the banana to avoid collision.
* **Code:**

```python
current_position = robot.state_description()
robot.move_gripper_to(position=[grasp_position[0], grasp_position[1], 0.1], orientation=grasp_orientation,
gripper=Gripper.LEFT)
```

* environment output not shown for brevity *

* **Summary:** The left gripper moved upwards to a z-coordinate of 0.1 while maintaining the same x, y and orientation. The robot state confirms this.
```

Figure 33 | Example of grasping and lifting by Gemini whilst carrying out a robot control task. Output is by Gemini except for the environment feedback and “* environment output not shown for brevity *” (shown in gray). Other colors refer to the following: blue — planning; orange — code; green — analysis or discussion.

```
```python
Step 4: Close the left gripper.

4.1. Goal: Close the left gripper to grasp the banana.
4.2. Grasping: Close the gripper to grasp the banana.
4.3. No trajectory needed.
robot.close_gripper(gripper='LEFT')
```

# Robot State:
LEFT: position: [-0.33 0.2 0.02], orientation: [153.67 88.78 75.54], distance_between_fingers_meters: 0.0,
commanded_state: closed
RIGHT: position: [ 0.17 -0.02 0.3 ], orientation: [-2.0e-02 -1.3e-01 -1.8e+02], distance_between_fingers_meters:
0.0, commanded_state: closed

The left gripper closed, but the distance between fingers is 0.0, which means the grasp failed.
I need to re-plan the grasp. I will move the gripper slightly above the banana and try grasping again.

*intermediate steps not shown for brevity*

# Robot State:
LEFT: position: [-0.31 0.16 0.01], orientation: [ 139.93 88.51 -131.03], distance_between_fingers_meters: 0.04,
commanded_state: closed
RIGHT: position: [ 0.17 -0.02 0.3 ], orientation: [-2.0e-02 -1.1e-01 -1.8e+02], distance_between_fingers_meters:
0.0, commanded_state: closed

The left gripper closed and the distance between fingers is 0.04, which means the grasp was successful.
```

Figure 34 | Examples of error detection and retrying by Gemini when carrying out a robot control task. Output is by Gemini except for the environment output and “*intermediate steps not shown for brevity*” (shown in gray). Other colors refer to the following: orange — code; green — analysis or discussion.

C. Robot Actions with Gemini Robotics

C.1. Evaluation procedure

Real world robotics performance metrics (e.g., success rate and/or progress) can be noisy, because conducting experiments on robots is subject to constantly changing environments and deteriorating hardware. To address these concerns, each evaluation task (defined by an instruction and initial conditions) is run with multiple trials. These trials are repeated for each of the target models (e.g., Gemini Robotics and baselines). To reduce bias from environmental factors (e.g., network latency, wear-and-tear of motors, lighting changes, etc.) and eliminate operator bias, the target models are evaluated for each trial back-to-back in random order (A/B testing). This allows us to use a pairwise t-test to more robustly evaluate improvements over baselines.

Each evaluation is marked either success or failure (0 for failure, 1 for full completion). Furthermore, we also use a continuous metric, progress score, between 0 and 1, reflecting the proportion of the task completed. Given the difficulty of some of our tasks — long-horizon, highly dexterous, and in challenging generalization scenarios — reporting the continuous progress metric offers another insightful metric for comparing model performance.

C.1.1. *Evaluation tasks to test out-of-the-box in-distribution performance*

All of the evaluation tasks used for Figure 16 can be found in Figure 35, including instruction and an example of initial scene configuration.

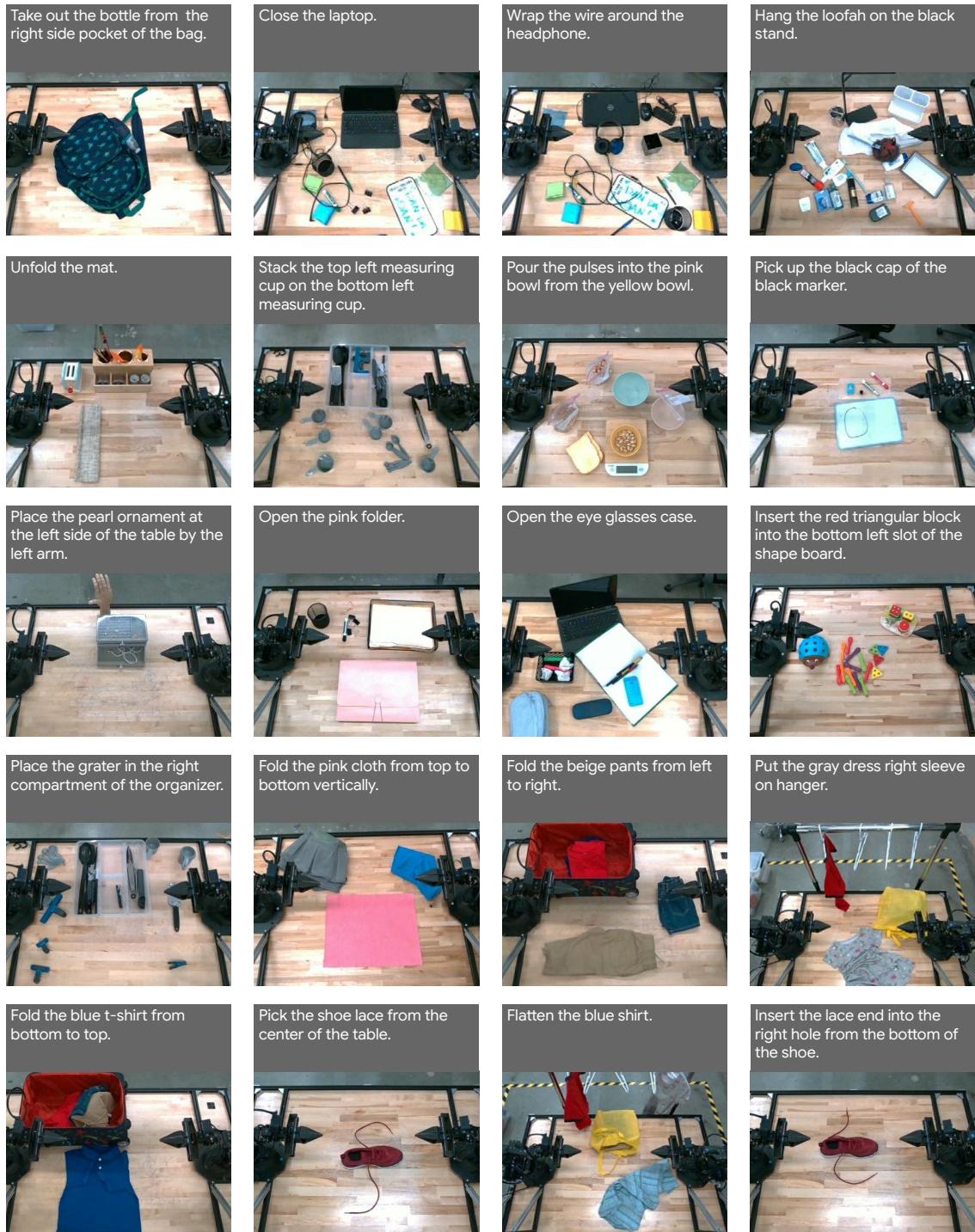


Figure 35 | Initial scene configuration and instructions used for our out-of-the-box evaluation in Figure 16.

C.1.2. Evaluation tasks for instruction following analysis

Figure 36 shows the 5 scenes and the 25 instructions used to assess Gemini Robotics instruction following in Section 3.3.

| Initial scene | Instruction #1 | Instruction #2 | Instruction #3 | Instruction #4 | Instruction #5 |
|---|--|--|---|--|--|
|  | Put the blue bar in the right side of the grey container. | Put the banana in the bottom of the brown bag. | Place the blue bar below the brown lunch bag. | Move left red grapes to the top left corner of the table. | Put the brown bar in the orange lunch bag. |
|  | Pick up the toothpaste and place it on the blue towel. | Pick up the green scrub and place it in the bottom compartment of the caddy. | Place the blue towel in the bottom compartment of the caddy. | Place the toothpaste in the bottom compartment of the caddy. | Pick up the deodorant and place it to the left of the pink sponge. |
|  | Place the blue clip to the right of the yellow sticky notes. | Pick up the calculator and place it on the right side of the table. | Place the blue clip in the top black container. | Pick up the blue sticky notes and place it in the top black container. | Pick up the scissors and place it on the bottom of the table. |
|  | Pick the bottom ring and place it on the left side of the table. | Pick up the calculator and place it on the top right of the table. | Pick up the pink stapler and place it on the black organizer. | Pick up black marker and place it on pink organizer. | Pick up sticky notes and place on black organizer. |
|  | Put the banana in the top bowl. | Put the mango in the red bowl. | Place the top bowl on the bottom bowl. | Place grapes next to the bottom bread. | Put the grapes and the mango in the same bowl. |

Figure 36 | Examples of the initial scene configurations and instructions used for the instruction following analysis in Section 3.3.

C.1.3. Evaluation tasks for generalization study

In this Section we describe all the tasks and variations we used for the generalization results of Figure 21.

C.1.3.1 Visual and Instruction generalization tasks

We consider 4 different tasks in a scene including objects to be packed in a lunch bag. In order to assess instruction generalization, we ask the robot to solve the task using different instructions by 1) adding typos, 2) translating the instruction to a different language (Spanish), 3) rephrasing the instruction, and 4) adding descriptive modifiers. See Figure 37 for detailed examples.

| Initial scene | In-distribution | Typo | Multilingual | Rephrasing | Descriptive |
|---------------|---|--|---|--|--|
| | Put the top left green grapes into the right compartment of the grey box. | Put the top lft gren grapes into the rht comprtment of the grey bx. | Coloque las uvas verdes de la parte superior izquierda en el compartimento derecho de la caja gris. | Pick up the green grapes and place them in the largest container of the grey box. | Pick the green grapes (top left) and put them in the grey box (right compartment). |
| | Put the brown bar in the top pocket of the lunch bag. | Put the brwn bar into the top pckt of the lnc bag. | Coloque la barra marrón en el bolsillo superior de la bolsa del almuerzo. | Put the brown bar into the lunch bag's top pocket. | Pack the brown bar in the top of the lunch bag. |
| | Put the top right red grapes into the top left compartment of the grey box. | Put the top rht rd grapes into the op lft compartment of th gry box. | Coloque las uvas rojas de la parte superior derecha en el compartimento superior izquierdo de la caja gris. | Pick up the top right red grapes and place them in the top left container of the grey box. | Pick the red grapes (top right) and put them in the grey box (top left compartment). |
| | Unzip the lunch bag completely. | Uzip the luch bag completly. | Abra completamente la cremallera de la bolsa del almuerzo. | Open the lunch bag. | Unzip the bag. |

Figure 37 | Examples of initial scene configurations and instructions used for instruction generalization evaluations in in Section 3.4.

We then test our model ability to generalize to visual variations of the scene by 1) adding novel distractor objects, 2) by replacing the background (wooden tabletop) with a blue-white cloth, and 3) by changing the lighting of the scene. All these variations are not captured in the training data. See Figure 38 for detailed examples.



Figure 38 | Examples of initial scene configurations and instructions used for visual generalization evaluations in Section 3.4.

C.1.3.2 Action generalization tasks

We consider 6 different tasks across multiple scenes. We analyse action generalization across two different axes: 1) OOD object positions and 2) different target object instance with different color, shape or size. See Figure 39 for details.

C.1.3.3 Task and progress definition

In Figure 21, we reported Progress Score, the continuous metric that captures the nuances of the performance beyond the success rate of the binary categorization between success and failure. Here is the definition of progress for each task.

- “**Put the top left green grapes into the right compartment of the grey box.**” This task requires the robot to pick up the green grapes and drop them in the right compartment of the grey bento box.
 - 1.0 : if the grapes are placed in the correct compartment;

| In-distribution | Different initial positions | | In-distribution | New object instance | |
|--|-----------------------------|--|--------------------------------------|---------------------|--|
| | | | | | |
| Put the legos into the lego bag. | | | Tighten the cap of the water bottle. | | |
| | | | | | |
| Open the bottom drawer of the jewelry box. | | | Fold the dress. | | |
| | | | | | |
| Put banana in bowl with handover. | | | Unzip the lunch bag completely. | | |

Figure 39 | Examples of initial scene configurations and instructions used for action generalization evaluations in Section 3.4.

- 0.5 : if the grapes are picked and placed in the wrong compartment;
- 0.25: if the grapes are picked but never placed;
- 0.0 : if anything else happens.
- “**Put the brown bar in the top pocket of the lunch bag.**” This task requires the robot to pick up the brown bar and place it in the top pocket of the lunch bag.
 - 1.0 : if the brown bar is placed in the lunch bag’s top pocket;
 - 0.75: if the brown bar is placed in the lunch bag (either pocket);
 - 0.25: if the robot picks up the brown bar;
 - 0.0 : if anything else happens.
- “**Put the top right red grapes into the top left compartment of the grey box.**” This task requires the robot to pick up the red grapes and drop them in the top-left compartment of the grey bento box.
 - 1.0 : if the grapes are placed in the correct compartment;
 - 0.5 : if the grapes are picked and placed in the wrong compartment;
 - 0.25: if the grapes are picked but never placed;
 - 0.0 : if anything else happens.
- “**Unzip the lunch bag completely.**” This task requires the robot to fully unzip the lunch bag.
 - 1.0 : if the robot fully unzips the lunch bag;
 - 0.5 : if the robot successfully grasps the zipper and partially un-zips it;
 - 0.25: if the robot successfully identifies and grasps the zipper tag;
 - 0.0 : if anything else happens.

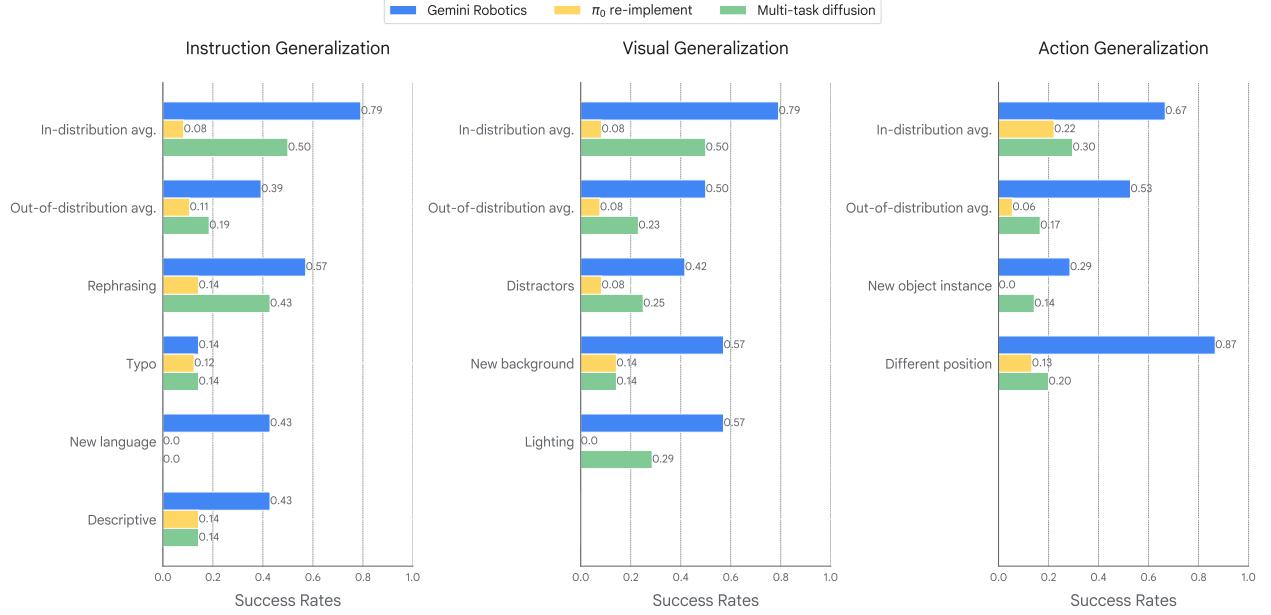


Figure 40 | Breakdown of Gemini Robotics generalization capabilities with success rate. Gemini Robotics consistently outperforms the baselines and handles all three types of variations more effectively. Notably, even when baselines experience catastrophic failure — such as with instructions in a new language or visual variations of the target object, Gemini Robotics still achieves non-zero performance.

- **“Put the legos into the lego bag.”** This task requires the robot to pick up 4 lego blocks (one-by-one) and then place them into the lego bag.
 - 1.0 : if all 4 blocks are placed in the bag;
 - 0.75: if 3 blocks are placed in the bag;
 - 0.50: if 2 blocks are placed in the bag;
 - 0.25: if 1 block is placed in the bag;
 - 0.0 : if no blocks are in the bag.
- **“Tighten the cap of the water bottle.”** This task requires the robot to tighten the caps of various (plastic and metal) bottles.
 - 1.0 : if the robot has tightened the cap by at least one full rotation;
 - 0.5 : if the robot begins to tighten the cap but does not finish one rotation;
 - 0.1 : if the robot grasps the water bottle’s cap;
 - 0.0 : if anything else happens.
- **“Open the bottom drawer of the jewelry box.”** This task requires the robot to open the bottom drawer of the jewelry box.
 - 1.0 : if the robot opens the bottom drawer of the jewelry box;
 - 0.25: if the robot grasps the bottom drawer of the jewelry box;
 - 0.0 : if anything else happens.
- **“Fold the dress.”** This task requires the robot to fold different dresses.
 - 1.0 : if the dress is folded with all the correct folds;
 - 0.25: if the robot gets at least one (even messy) fold;
 - 0.0 : if anything else happens.
- **“Put banana in bowl with handover.”** This task requires the robot to pick up the banana with one arm, hand it over to the other arm, and then place it in the bowl.

- 1.0 : if the robot picks the banana, hands it over, and places it in the bowl;
- 0.5 : if the robot picks the banana and hands it over, or if the robot places the banana in the bowl without handing it over;
- 0.25: if the robot picks the banana and then drops it;
- 0.0 : if the robot does not pick the banana.

For completeness, we also include the plot of success rate below (Figure 40).

C.2. Baselines

Our Gemini Robotics model is compared against three baselines that represent the state-of-the-art in vision-language-action models, multi-task learning and dexterity, respectively.

π_0 *re-implement*: This is a faithful re-implementation, to the best of our knowledge, of π_0 , an open-weights dexterous VLA model (Black et al., 2024) consisting of a diffusion transformer “action expert” policy that attends to latents from an underlying PaliGemma VLM (Beyer et al., 2024). The π_0 model architecture and weights have been publicly released by the authors (openpi). We re-implement this model to be compatible with our scalable training infrastructure to consume our diverse actions training data. We train this model on the same data mixture as Gemini Robotics. On internal evaluations, we find that our π_0 *re-implement* trained on our data mixture outperforms the π_0 *openpi* checkpoint out of the box, as well as π_0 *openpi* fine-tuned for individual tasks (Fig. 41); hence, we report numbers from our re-implementation throughout the paper. In Section 3, we use a batch size of 2048 and train it for 300K steps. In Section 4, we fine-tune from the checkpoint from Section 3, using the same batch size for 50K steps. We also carefully select the checkpoints for evaluation to ensure fair comparisons.

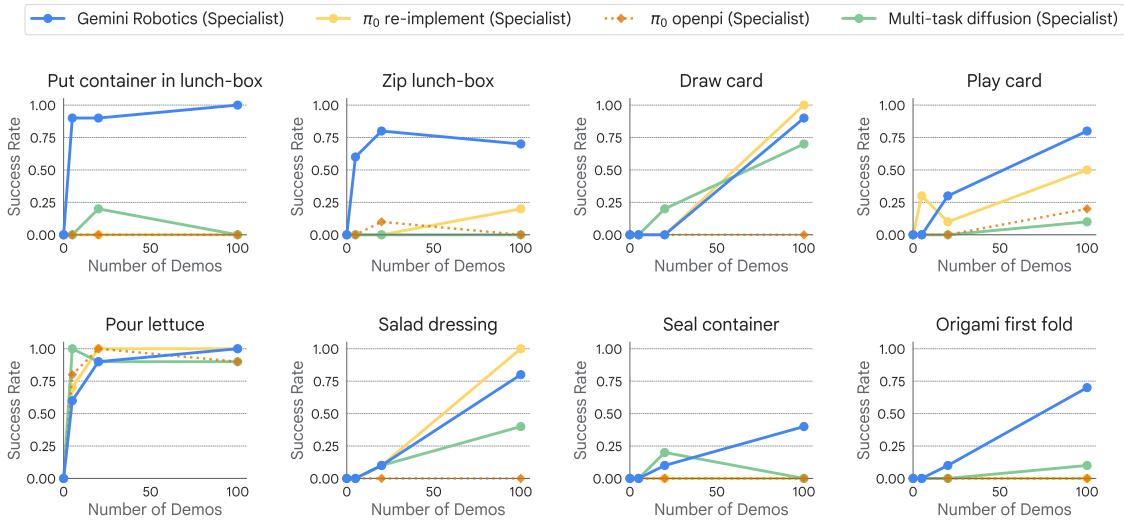


Figure 41 | Fast adaptation results (Section 4.3) with the π_0 *openpi* baseline. The results are consistent between π_0 *openpi* and π_0 *re-implement* in 5 out of 8 tasks, while our own implementation achieves better results for the other 3 tasks.

Multi-task diffusion: This is a diffusion policy architecture inspired by ALOHA Unleashed (Zhao et al., 2025) and modified to be task-conditioned. We add a CLIP text encoder (Radford et al., 2021) to encode the natural language task string, while the original model of Aloha Unleashed only works in single-task settings. In Section 3, we use a batch size of 512 and train it for 2M steps on the identical action data mixture. For experiments in Section 4, we start from the checkpoint from Section 3,

use the same batch size and fine-tune it for 1M steps. The batch size, training steps and evaluation checkpoints are empirically determined to optimize the model’s final performance.

Single-task diffusion: This is the same diffusion policy architecture from ALOHA Unleashed (Zhao et al., 2025). We do not include this baseline in Section 3 because it is not designed for multi-task learning. For all our specialization and adaptation experiments in Section 4, we initialize the model from scratch, use a batch size of 512 and train it for 2M steps. Similarly, the batch size, training steps and evaluation checkpoints are empirically determined to optimize the model’s final performance.

D. Specializing and Adapting Gemini Robotics for Dexterity, Reasoning, and New Embodiments

D.1. Long-horizon dexterity

D.1.1. Evaluation procedure

These evaluations primarily focus on in-distribution performance, with defined initial conditions for each task. We conduct 20 trials per task per model. The spelling game task is the only exception, where performance is analysed over 12 trials, including both in-distribution results (6 trials for printed picture cards) and out-of-distribution results (6 trials for hand-drawn sketches).

In Section 4.1, we report success rates for each of the six dexterous tasks. Here, we additionally show the progress scores for each task in Figure 42 to get a more fine-grained picture of the differences between the performance of Gemini Robotics and the baseline models.

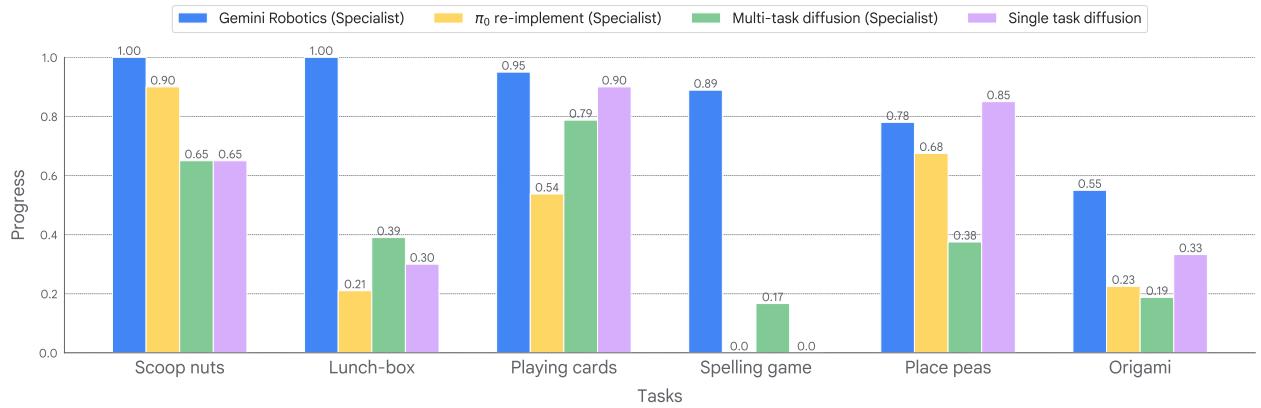


Figure 42 | Average task progress score on new, dexterous and long-horizon tasks after specialization. This Figure complements Figure 23. The average task progress score highlights that on all tasks but Spelling game, all methods show non-zero progress towards the completion of the tasks. However, Gemini Robotics outperforms almost all baselines across all tasks except for the single task diffusion on the Place peas task according to this metric.

The definition of the task can be found in Section 4.1, and below we define the progress scores for each task:

- “Make an origami fox”
 - 1.0 : if the robot fully folds the origami fox;
 - 0.75: if the robot completes the first three folds;
 - 0.5 : if the robot completes the first two folds;

- 0.25: if the robot completes the first fold;
- 0.1 : if the robot attempts to make the first fold;
- 0.0 : if anything else happens.

- “**Pack a lunch-box**”

- 1.0 : if the lunch-box contains all required items inside it and is fully zipped;
- 0.75: if the lunch-box contains all required items inside it: the bread inside the ziploc, an energy bar, and the sealed container with grapes inside;
- 0.5 : if the robot transfers the zipped ziploc containing the bread into the lunch-box;
- 0.25: if the robot inserts the bread in the ziploc bag and zips the ziploc bag;
- 0.1 : if the robot inserts the bread in the ziploc bag;
- 0.0 : if anything else happens.

- “**Spelling board game**”

- 1.0 : if the robot spells all three letters correctly;
- 0.66: if the robot spells the first two letters correctly;
- 0.33: if the robot spells the first letter correctly;
- 0.0 : if anything else happens.

- “**Play a game of cards**”

- 1.0 : if the robot draws 3 cards, plays 1 card, and folds the remaining cards;
- 0.75: if the robot plays more than 1 card after 3 cards are drawn;
- 0.5 : if the robot draws 3 cards but fails to play any card;
- 0.25: if the robot draws 1 card;
- 0.0 : if anything else happens.

- “**Add snap peas to salad**”

- 1.0 : if the robot places at least 3 peas into the salad bowl with the tongs and then places the tongs back on the table;
- 0.5 : if the robot places at least 1 pea into the salad bowl with the tongs;
- 0.0 : If anything else happens.

- “**Add nuts to salad**”

- 1.0 : if the robot scoops at least 1 scoop of nuts, adds them to the salad bowl, and places the spoon back on the table;
- 0.5 : if the robot scoops at least 1 scoop of nuts and adds them to the salad bowl;
- 0.0 : if anything else happens.

D.2. Enhanced reasoning and generalization

D.2.1. Evaluation procedure

For the reasoning-enhanced version and the vanilla Gemini Robotics models, we perform 100 trials across 8 different tasks, each with a unique initial scene configuration. The tasks are grouped into the following categories, based on what capabilities they are designed to measure: One-step Reasoning, Semantic Generalization, and Spatial Understanding.

D.2.1.1 One-step Reasoning Tasks

For tasks in this category, the instruction specifies the objects of interest and/or the manipulation action indirectly, e.g., via their properties or affordances:

- “**Put the coke can into the same colored plate.**” In this task the model must place the Coca-cola can into the red plate instead of the different colored distractor plates.
- “**Sort the bottom right mouse into the matching pile.**” In this task the model must sort the white toy mouse at the bottom right into a pile of white toy mice, instead of the distractor piles of brown and grey mice; all of these mice, as well as the task of sorting objects based on their color, are unseen in training.
- “**I need to brush my teeth, pick up the correct item.**” The model must retrieve a toothpaste tube through cluttered distractors (deodorant, banana, and mango).

For these three instructions, the keywords of reasoning (*same*, *matching*, *correct*) are unseen in the training dataset of robot actions.

D.2.1.2 Semantic Generalization Tasks

These tasks require semantic and visual understanding beyond the complexity of the Instruction Generalization tasks in Section 3.4.

- “**Put the Japanese fish delicacy in the lunch-box.**” The model must decide that the sushi is the target object among various distractor objects, and pack the sushi into the lunch-box.
- “**Pick up the full bowl.**” The model must lift up the bowl filled with dice (unseen in training) instead of the two empty bowls (seen in training).

For these two instructions, the language describing the new semantic concept (*Japanese fish delicacy*, *full*) are unseen in the training dataset of actions.

D.2.1.3 Spatial Understanding Tasks

These tasks require understanding concepts about relative and absolute spatial relationships.

- “**Pack the smallest coke soda in the lunch-box.**” The model must pack the mini-size Coca-cola can instead of distractor full-size Coca-cola cans, and place it into the lunch-box. The language describing the spatial concept under evaluation (*smallest*) is unseen in training.
- “**Put the cold medicine in the bottom/top left bowl.**” The model must find the cold medicine box out of distractors (a indigestion medicine and hand sanitizer), all of which are unseen in training, and place it into the correct bowl out of three distractor bowls placed in different locations around the table.

For these two instructions, the language describing the new objects (*coke soda*, *medicine*) is unseen during training, while the language describing the spatial concepts are present varying amounts in the training distribution of action labels: *smallest* is unseen, *top left* and *bottom left* are rare, and *left* and *right* are common.

D.3. Fast adaptation to new tasks

D.3.1. Tasks and evaluation details

We also study the capability of Gemini Robotics to adapt rapidly (using up to 100 episodes of demonstration) to new tasks. We choose shorter segments sampled from the demonstrations for the

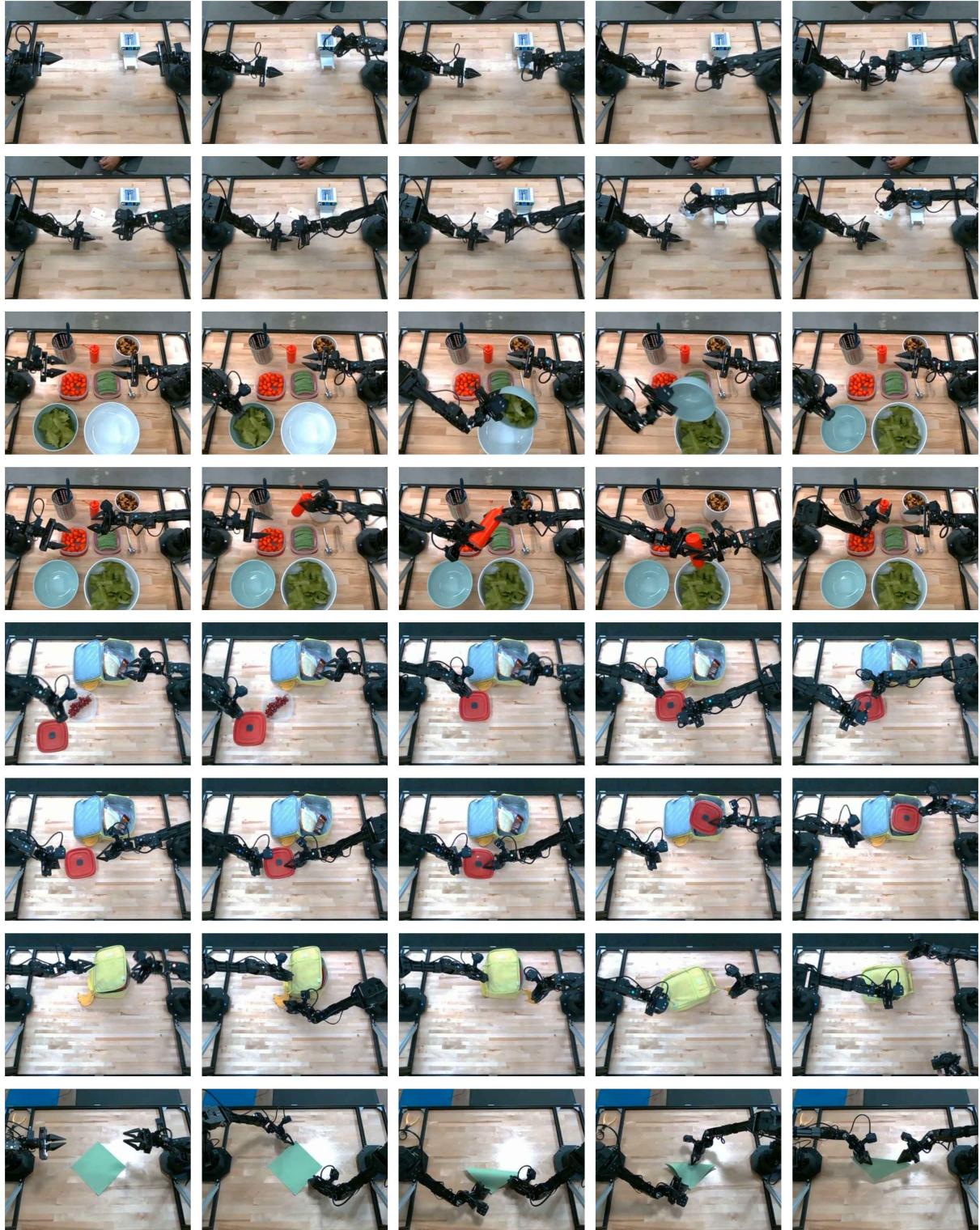


Figure 43 | Tasks for fast adaptation experiments. From top to bottom: “Draw card”, “Play card”, “Pour lettuce”, “Salad dressing”, “Seal container”, “Put container in lunch-box”, “Zip lunch-box”, and “Origami first fold”.

long-horizon dexterous tasks (Section 4.1) as the new tasks. Note that in this section, we fine-tune the Gemini Robotics checkpoint directly from Section 3, which has never seen any demonstrations

introduced in Section 4.1. This ensures that it is a fair test for adapting to *new* tasks. The evaluated tasks used in Figure 26 are:

- “**Draw card.**” The robot must draw one card from the card dispenser machine by pushing the green button, picking up the card, and placing the card into the left gripper.
- “**Play card.**” The robot must pick one of the three cards from the robot gripper and play it by placing it on the table.
- “**Pour lettuce.**” The robot must pour lettuce from the green bowl into the white salad mixing bowl.
- “**Salad Dressing.**” The robot must pick up the salad dressing bottle and squeeze the bottle over the white salad mixing bowl.
- “**Seal container.**” The robot must close the lid of the Tupperware container by aligning and pressing down on multiple locations of the container lid.
- “**Put container in lunch-box.**” The robot must pick up the Tupperware container and place it in the open lunch-box.
- “**Zip lunch-box.**” The robot must fully zip up the lunch box using the zipper tag.
- “**Origami first fold.**” The robot must diagonally fold a square piece of construction paper into a triangle shape.

See Fig. 43 for an illustration of each of the fast adaptation tasks.

For each of the fast adaptation tasks described above, we report curves of success rate with increasing amount of demonstration data (5, 20 and 100 episodes) in Fig. 26 for Gemini Robotics and baselines. We run 10 trials and calculate the average success rate to draw each point in the plot. Given the short-horizon nature of these tasks, we do not define or report a progress score.

D.4. Adaptation to new embodiments

D.4.1. Tasks description

We test our Gemini Robotics model on the bi-arm Franka platform on 4 dexterous tasks relevant for industrial applications (example of rollouts in Fig. 44). We describe here the tasks and define the progress score for each of them:

- **Tape hanging on a workshop wall:** The robot must grasp a tape from the desk and hang it on a hook on the workshop wall.
 - 1.0: If the robot succeeds in handing the tape over to the other arm, hangs it to the correct hook on the wall and moves the arms away;
 - 0.9: If the robot succeeds in handing the tape over to the other arm and hangs it to the correct hook on the wall;
 - 0.5: If the robot succeeds in handing the tape over to the other arm;
 - 0.1: If the robot picks up the tape;
 - 0.0: If anything else happens.
- **Plug insertion into socket:** One arm must grasp a UK electric plug and insert it into a socket to turn on a light, while the other arm must stabilize the socket.
 - 1.0: If the robot successfully inserts the plug into the socket, the light turns on and the robot moves the arms away;
 - 0.9: If the robot successfully inserts the plug into the socket and the light turns on;
 - 0.7: If the robot successfully aligns the plug with respect to the socket;

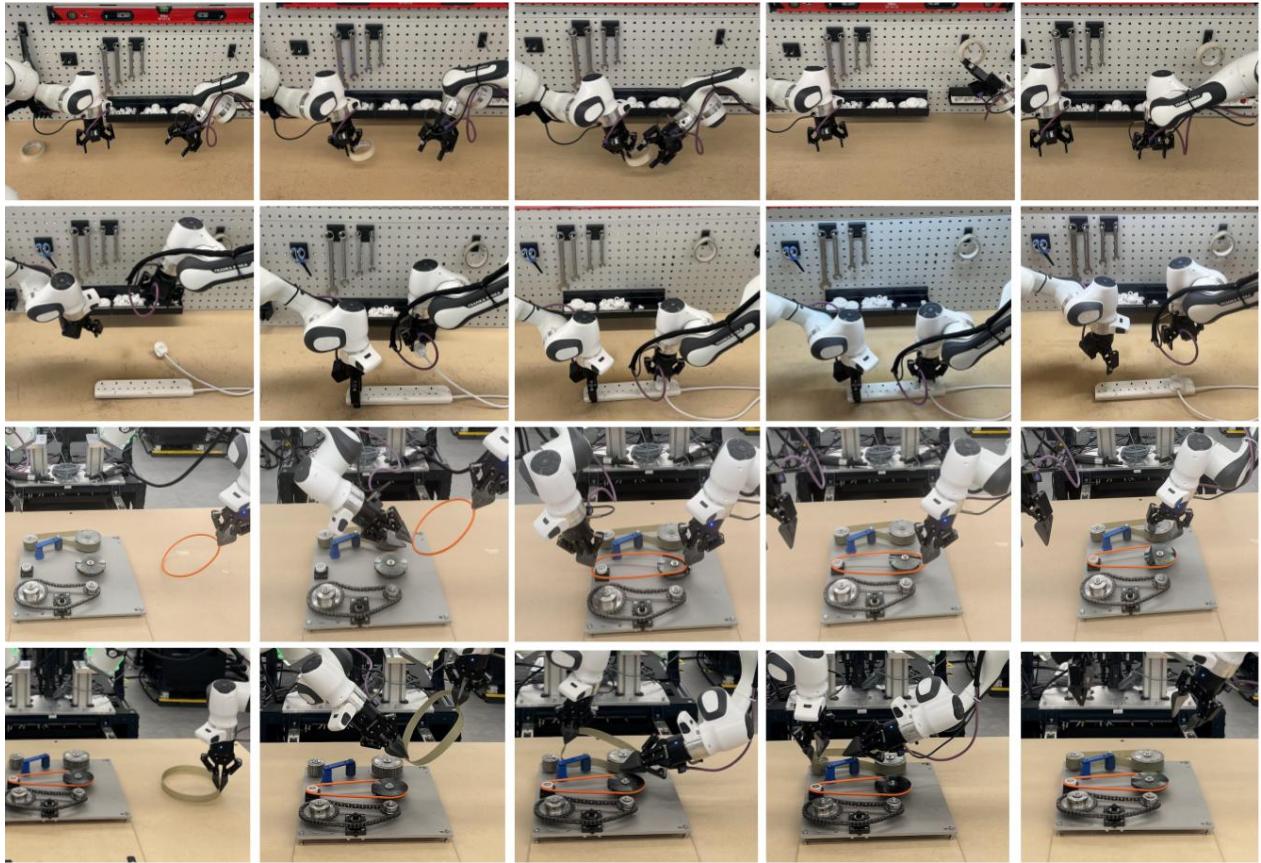


Figure 44 | Model rollouts for the 4 tasks with the bi-arm Franka robot. From top to bottom: tape hanging on a workshop wall, plug insertion into socket, round belt assembly in NIST task board 2, timing belt assembly in NIST task board 2.

- 0.3: If the robot successfully grasps the plug with one arm and holds the socket with the other arm;
- 0.2: If the robot successfully grasps the plug with one arm;
- 0.0: If anything else happens.
- **Round belt task of NIST Assembly Task Board 2 (ATB)** ([Kimble et al., 2020](#)): The robot must assemble a flexible industrial rubber band around a pulley system. This requires handing over the flexible and draping rubber band, and stretching it to fit onto the pulleys.
 - 1.0: If the robot inserts the rubber band on both wheels, ensures the belt is properly inserted and moves the arms away;
 - 0.9: If the robot inserts the rubber band on both wheels;
 - 0.7: If the robot inserts the rubber band on one of the wheels, but fails to place the rubber band on the other wheel;
 - 0.5: If the robot manages to grasp the rubber band with both arms;
 - 0.1: If the robot manages to grasp the rubber band with one arm;
 - 0.0: If anything else happens.
- **Timing belt task of NIST Assembly Task Board 2 (ATB)** ([Kimble et al., 2020](#)): The robot must assemble an industrial timing belt around a pulley system. This demands coordinated bi-arm action and significant force (roughly 40N) to pull the blue handle in the correct direction, enabling the timing belt's secure placement on the pulley system.
 - 1.0: If the robot inserts the belt on both wheels by applying enough force on the blue

handle, ensures that the belt is properly inserted and moves the arms away;

- 0.9: If the robot inserts the belt on both wheels by apply enough force on the blue handle and ensures that the belt is properly inserted;
- 0.7: If the robot inserts the belt on the large wheel, pushes the blue handle but fails to place the belt on the small wheel;
- 0.5: If the robot just inserts the belt on the large wheel.
- 0.3: If the robot manages to grasp the belt with both arms;
- 0.1: If the robot manages to grasp the belt with one arm;
- 0.0: If anything else happens.

D.4.2. Evaluation procedure

For in distribution evaluations, we run 20 trials per task by setting up the initial conditions based on the training data. We now describe the benchmark used to assess the visual and the action generalization performance for our Gemini Robotics model and the single task diffusion baseline.

D.4.2.1 Visual generalization tasks

For each task, we vary the appearance of the scene by 1) adding novel distractor objects, 2) altering the background and 3) changing the lighting condition. Example of initial scenes used for this analysis can be found in Figure 45.

D.4.2.2 Action generalization tasks

For each task, we assess action generalization by 1) putting the objects at positions that are not seen in the training data and 2) using different instances of objects to be manipulated that have different appearances, shapes or physical properties. Examples of initial scenes can be found in Figure 46.

For completeness, in addition to Figure 28 where we reported the progress score, Figure 47 reports the success rate of our model and the baseline across the tasks in the generalization benchmark.

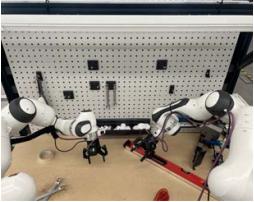
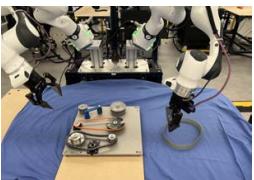
| In-distribution | Distractors | Different background | Different lighting conditions |
|--|---|--|---|
|  |  |  |  |
| Pass the tape from the left arm to the right arm and hang it on the wall. | | | |
|  |  |  |  |
| Hold the extension lead with the left arm and insert the plug in the rightmost socket of that lead with the right arm. | | | |
|  |  |  |  |
| Pick the orange round belt with the left arm and place it on the slide pulleys positioned on the NIST board 2. | | | |
|  |  |  |  |
| Pick the timing belt with the left arm and place it on the timing pulleys positioned on the NIST board 2. | | | |

Figure 45 | Example tasks used for visual generalization studies when the Gemini Robotics model is adapted to the bi-arm Franka robot.

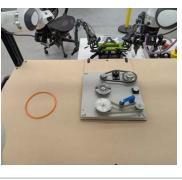
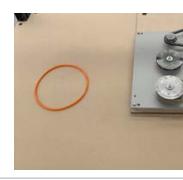
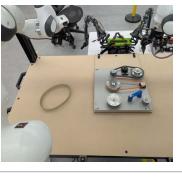
| In-distribution | Different initial positions | In-distribution | New object instance |
|--|---|---|---|
|  |  |  |  |
| Pass the tape from the left arm to the right arm and hang it on the wall. | | | |
|  |  |  |  |
| Hold the extension lead with the left arm and insert the plug in the rightmost socket of that lead with the right arm. | | | |
|  |  |  |  |
| Pick the orange round belt with the left arm and place it on the slide pulleys positioned on the NIST board 2. | | | |
|  |  |  |  |
| Pick the timing belt with the left arm and place it on the timing pulleys positioned on the NIST board 2. | | | |

Figure 46 | Example tasks used for action generalization studies when the Gemini Robotics model is adapted to the bi-arm Franka robot.

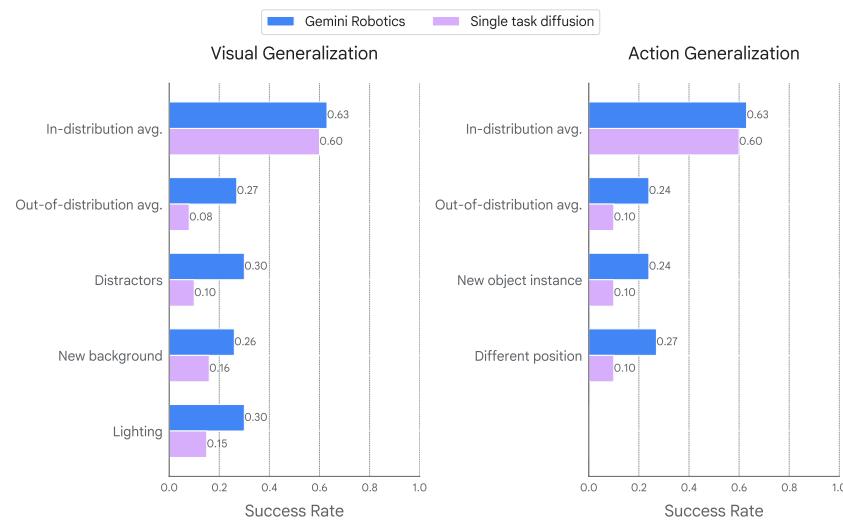


Figure 47 | Breakdown of generalization metrics (success rate) when the Gemini Robotics model is adapted to the bi-arm Franka robot. Similar to the progress score used in Fig. 28, our model significantly outperforms the diffusion baseline.