



# Diffusion Model-Augmented Behavioral Cloning

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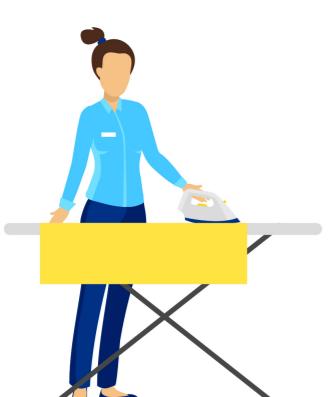


NTU Robot Learning Lab

## Imitation Learning

### Key Idea

Expert Demonstrations



### Expert Demonstration State and action sequences

	$s_{1:n_1}^1$	$s_{1:n_1}^2$	$s_{1:n_1}^3$	$s_{1:n_1}^4$	$s_{1:n_1}^5$
$a_{1:n_1}^1$	7.34 -3.17 2.06 3.18	-2.00 8.51 -8.63 3.61	-1.47 1.07 -1.88 3.04	4.98 -9.56 6.92 -1.80	4.68 -1.41 9.85 -1.73
	⋮	⋮	⋮	⋮	⋮
	$s_{1:n_M}^1$	$s_{1:n_M}^2$	$s_{1:n_M}^3$	$s_{1:n_M}^4$	$s_{1:n_M}^5$
$a_{1:n_M}^1$	5.32 2.59 -2.40 6.86	3.91 6.38 -5.21 1.27	1.64 -1.17 1.43 -1.61	2.56 -2.50 2.13 -1.26	5.31 -2.12 1.66 -1.24

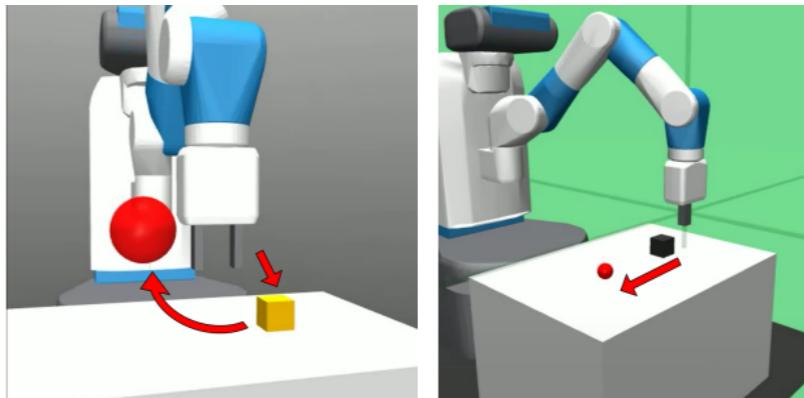
## Main Experiments

### Navigation



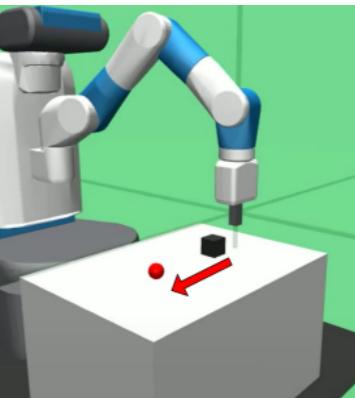
Maze

### Manipulation



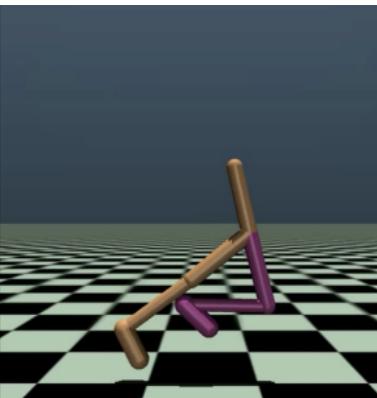
FetchPick

### Manipulation

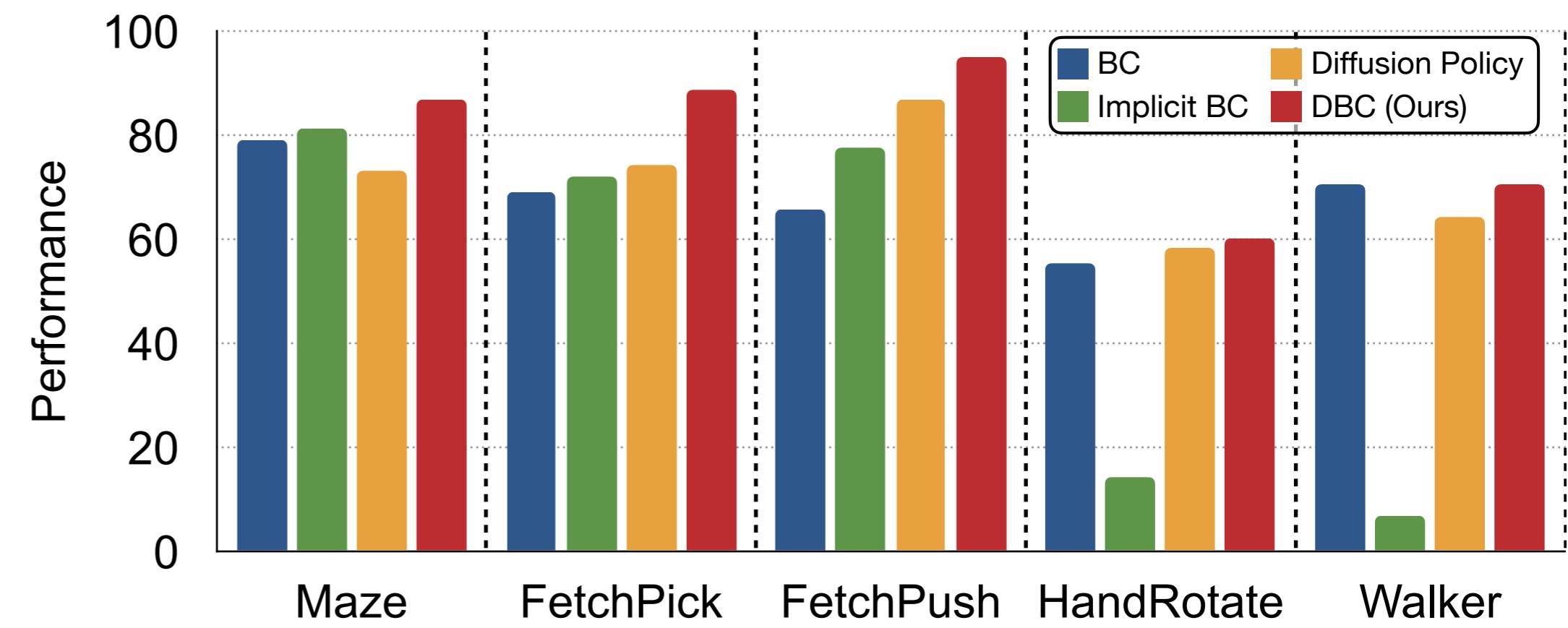


FetchPush

### Locomotion

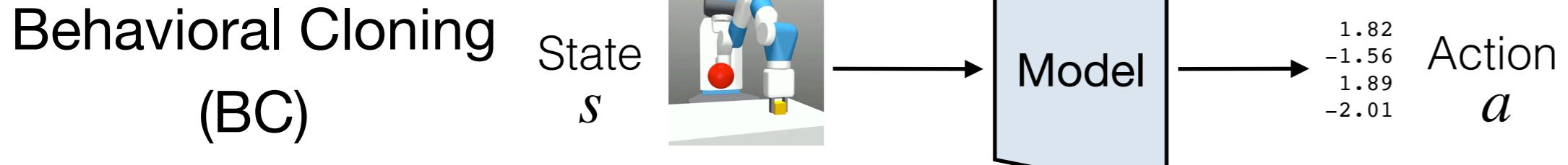


Walker

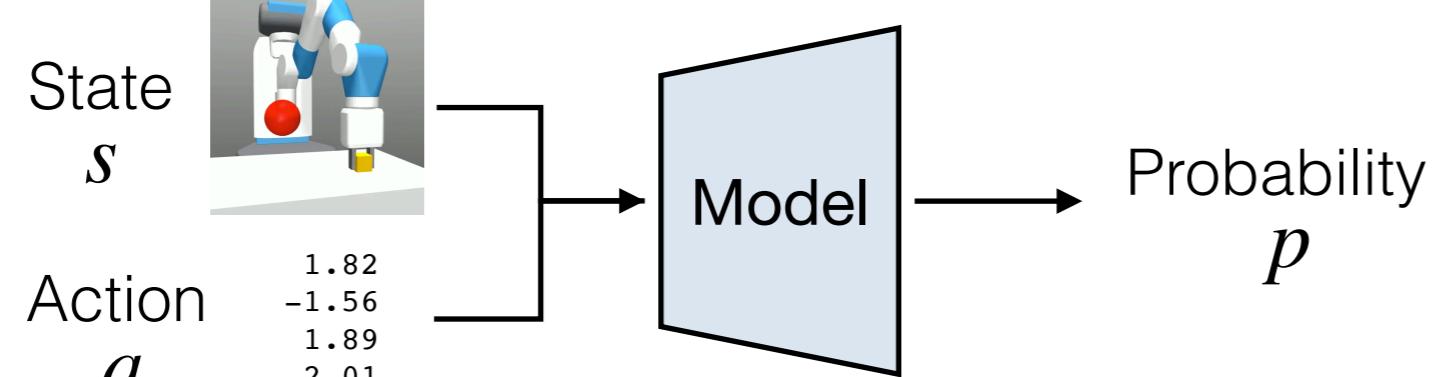


## Modeling Demonstrations

### Modeling the conditional probability $p(a|s)$



### Modeling the joint probability $p(s, a)$



Comparison	Conditional Probability $p(a s)$	Joint Probability $p(s, a)$
Advantages	<ul style="list-style-type: none"> <li>Training stability</li> <li>Inference efficiency</li> </ul>	<ul style="list-style-type: none"> <li>Better generalization</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>Poor generalization</li> </ul>	<ul style="list-style-type: none"> <li>Inference inefficiency</li> <li>Manifold overfitting</li> </ul>



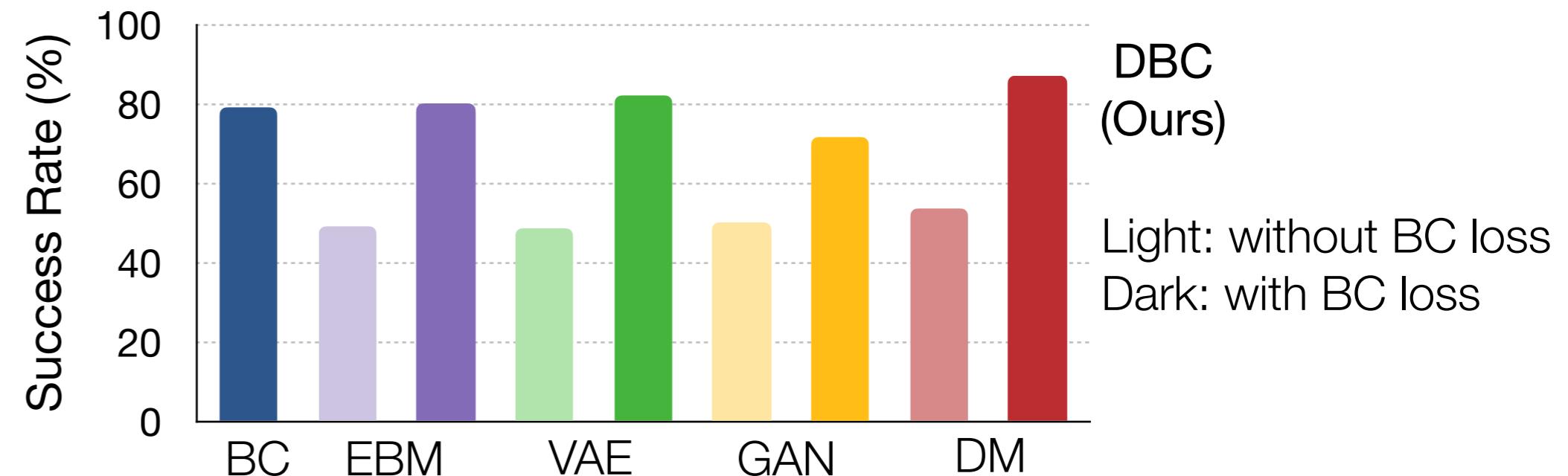
•  $\pi_{\text{Conditional}}$  generalizes poorly

•  $\pi_{\text{Joint}}$  suffers from manifold overfitting

## Ablation Studies

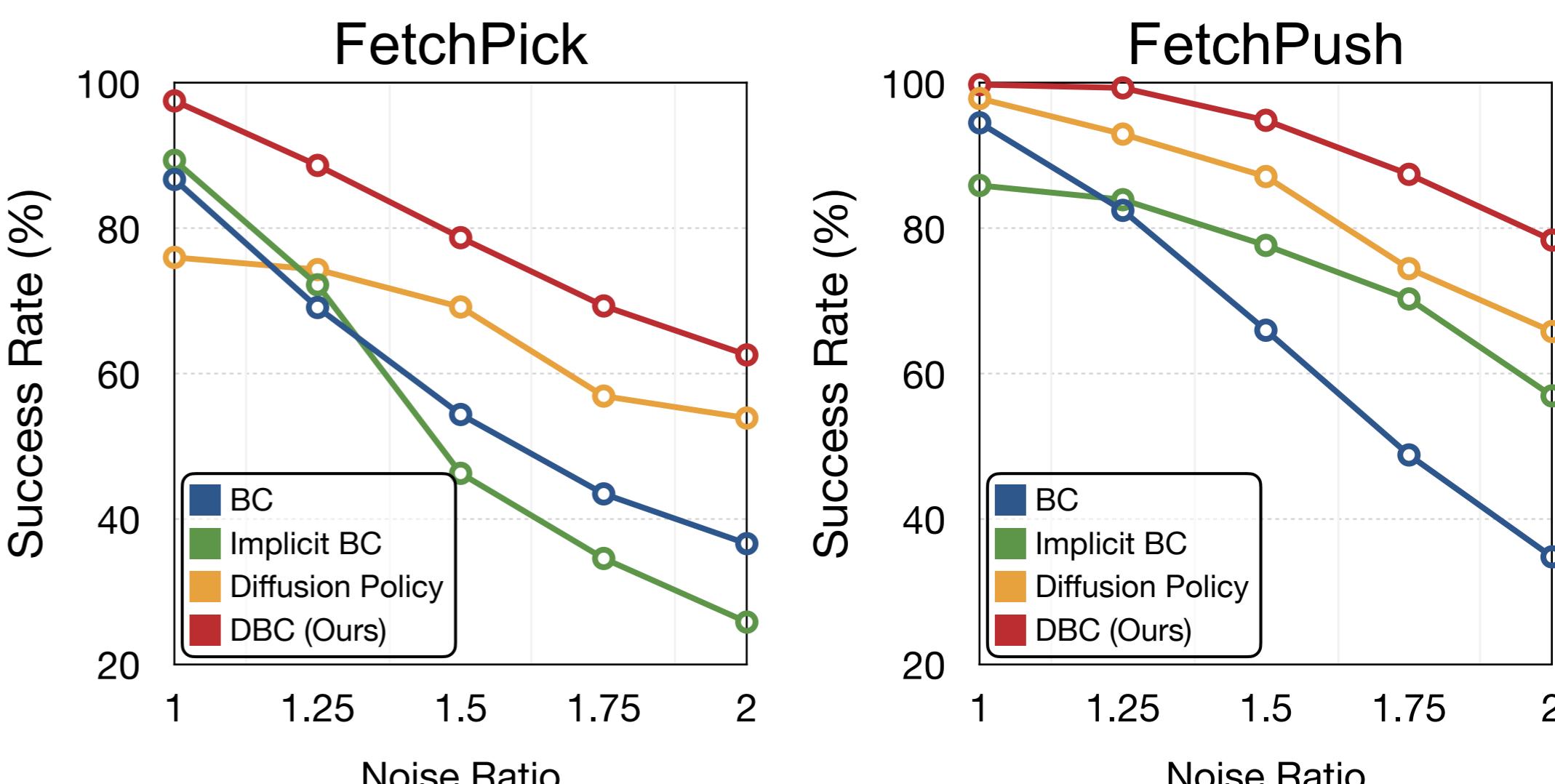
### Comparing generative models on Maze

- Energy-based model (EBM), variational autoencoder (VAE), generative adversarial network (GAN), diffusion model (DM)

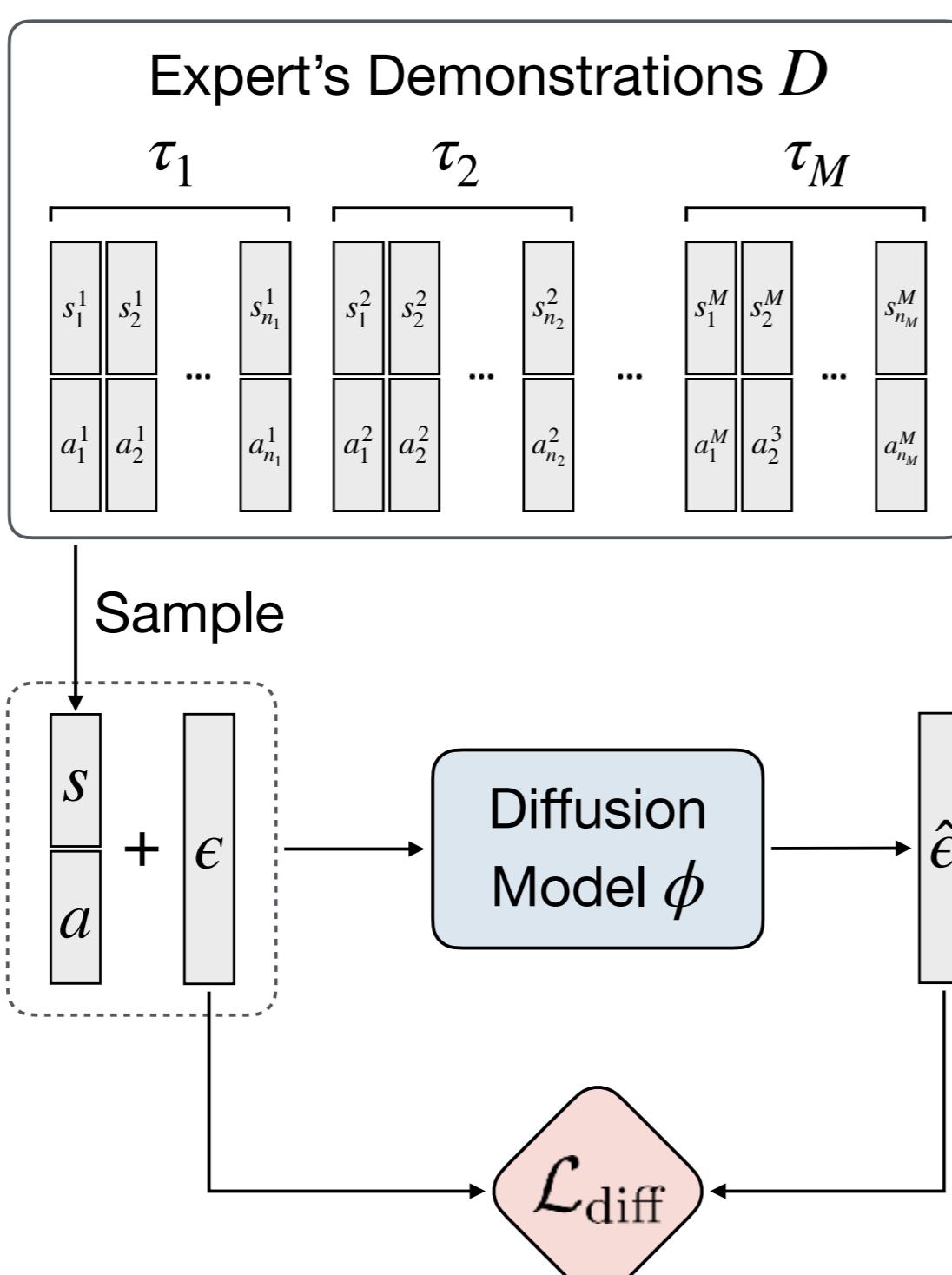


### Evaluating generalization performance on Fetch

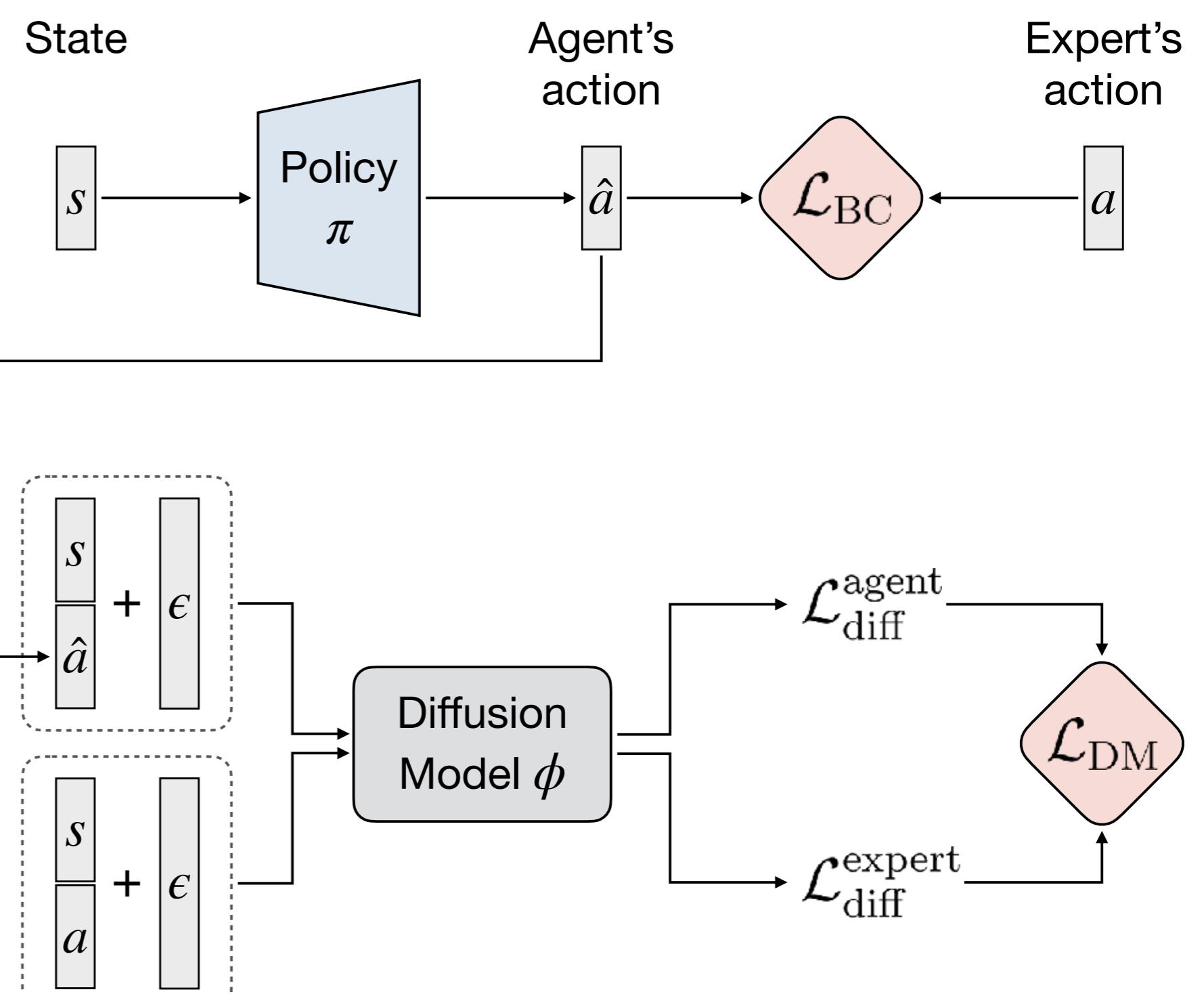
- Varying the noise added to initial states and goal locations



## Our Approach: Diffusion Model-Augmented Behavioral Cloning (DBC)



Stage 1: Learning a Diffusion Model



Stage 2: Learning a Policy with the Learned Diffusion Model