

# Learning to Contextualize Web Pages for Enhanced Decision Making of LLM agents

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## Introduction

Web page observations (e.g., HTML, AxTree) are often too long and full of unfamiliar UI elements, hindering decision-making of the LLM agents.

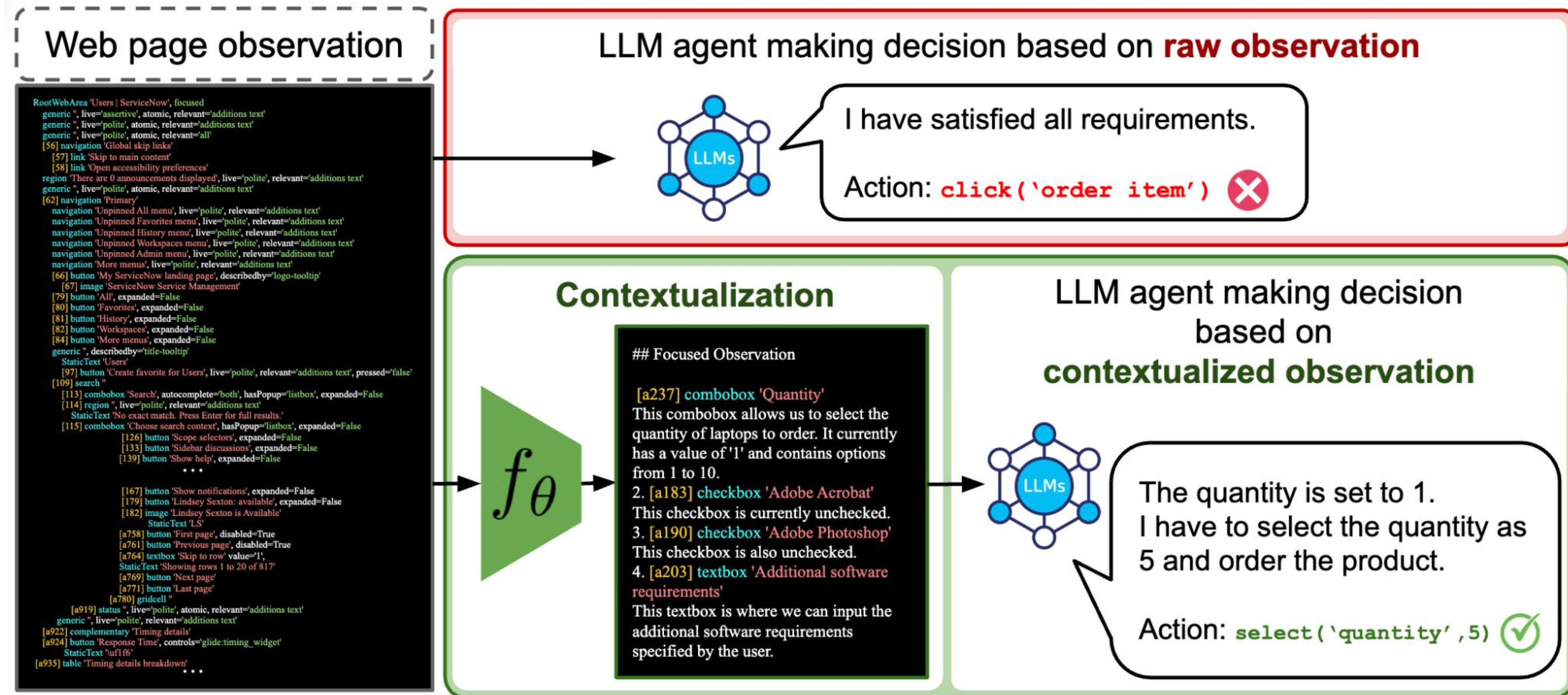


Figure 1. Contextualization module transforms complex web pages into a comprehensible format.

We introduce **LCoW**, a framework for **L**earning language models to **C**ontextualize complex **W**eb pages into a more comprehensible form, thereby enhancing decision making by LLM agents

## Method

### Training algorithm for contextualization module in LCoW

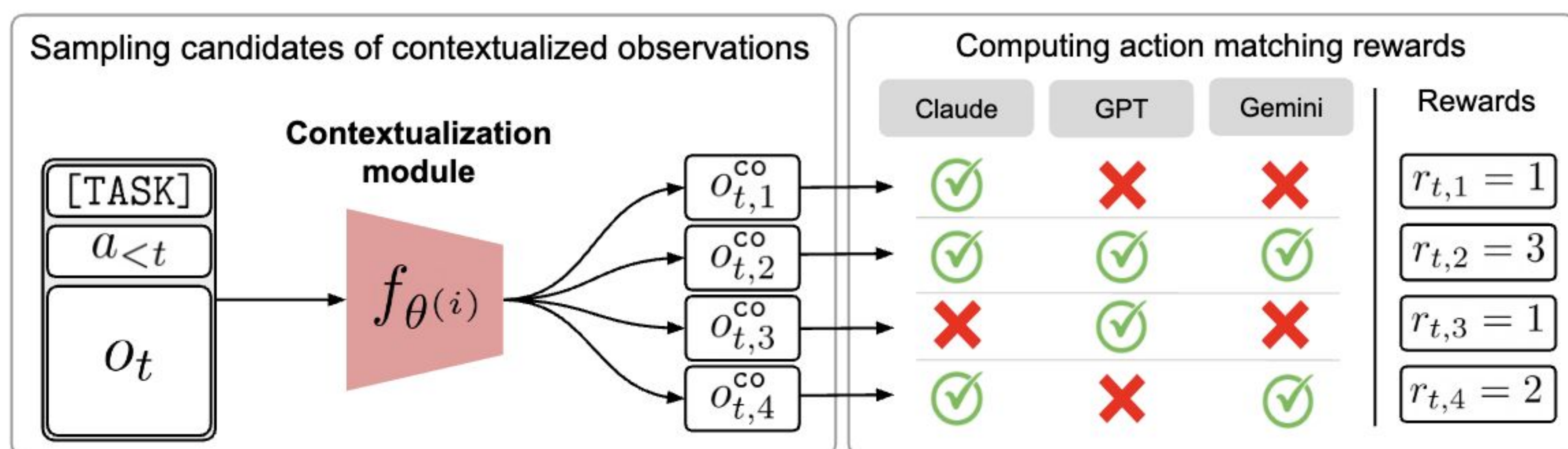


Figure 2. Illustration of action matching reward computation process.

- **Step 1 - Trajectory collection** (optionally, utilize demonstration)  
: Collect trajectories that successfully accomplish the instruction from environment.
- **Step 2 - Sampling optimal contextualization**
  - (a) Sample K contextualizations (temperature = 1.0).
  - (b) Measure how many LLM agents output correct action (action matching reward).
  - (c) Choose the contextualization with maximum action matching reward.
  - (d) If action matching rewards are zeros across every K contextualizations, we re-sample better contextualizations by prompting ground-truth action  $a_t$  as a hint.
- **Step 3 - Model update**  
: Train contextualization module with collected  $([TASK, O_t, a_{<t}], O_{t,*}^{co})$  pairs via SFT.

## Experiments

### WebShop Experiment

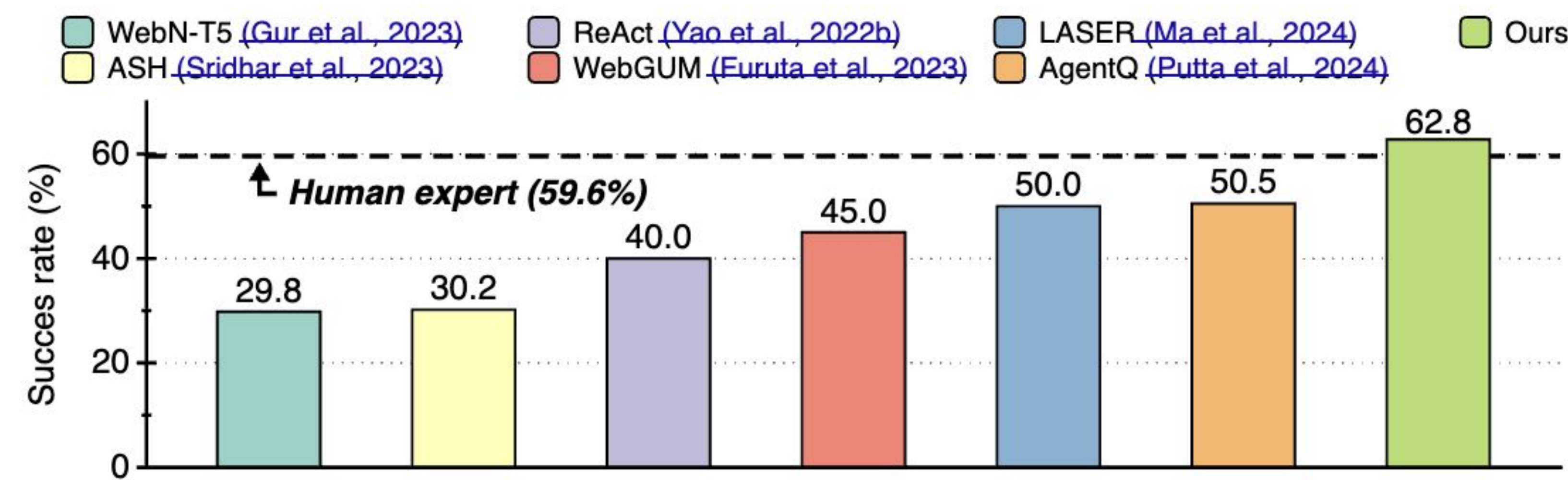


Figure 3. Comparison to baselines in WebShop benchmark.

	GPT-4o		Gemini-1.5-flash		Claude-3.5-Sonnet		Llama-3.1-70B (Unseen)	
	Success	Reward	Success	Reward	Success	Reward	Success	Reward
Raw observation	34.8%	0.496	43.6%	0.693	26.6%	0.336	34.2%	0.590
Self-ctx	26.2%	0.459	46.4%	0.608	12.4%	0.146	40.2%	0.547
LCoW (iter 1)	27.8%	0.545	46.4%	0.705	39.4%	0.600	39.2%	0.666
LCoW (iter 2)	46.0%	0.647	58.2%	0.796	58.8%	<b>0.780</b>	55.0%	0.781
LCoW (iter 3)	<b>50.6%</b>	<b>0.666</b>	<b>62.8%</b>	<b>0.803</b>	<b>59.8%</b>	<u>0.771</u>	<b>59.6%</b>	<b>0.803</b>

Table 1. Experimental result in WebShop benchmark.

- LCoW (contextualization module as fine-tuned Phi-3-mini-Instruct combined with an LLM agent using Gemini-1.5-flash) achieves **state-of-the-art results on the WebShop benchmark, outperforming human expert**.
- LCoW shows **consistent improvement** in performance over the iterations.
- Contextualization module is also effective when combined with LLM agent did not used for action matching reward computation (i.e., Llama-3.1-70B)

### WorkArena Experiment

	GPT-4o	Gemini-1.5-flash	Claude-3.5-Sonnet	Llama-3.1-70B (Unseen)	Llama-3.1-8B (Unseen)
Raw observation	38.2%	11.5%	44.8%	26.1%	1.2%
Self-ctx	43.0%	12.7%	50.3%	29.1%	7.3%
LCoW	<b>44.2%</b>	<b>41.2%</b>	<b>55.8%</b>	<b>40.0%</b>	<b>37.0%</b>

Table 2. Experimental result in WorkArena benchmark.

- LCoW improves the success rates of closed-source LLMs by an average of 15.6%, and demonstrates 23.7% average improvement in success rates for open-source LMs on the WorkArena benchmark.
- **LCoW + Llama-3.1-8B agent** shows better performance compared to **Llama-3.1-8B agent trained via BC**.

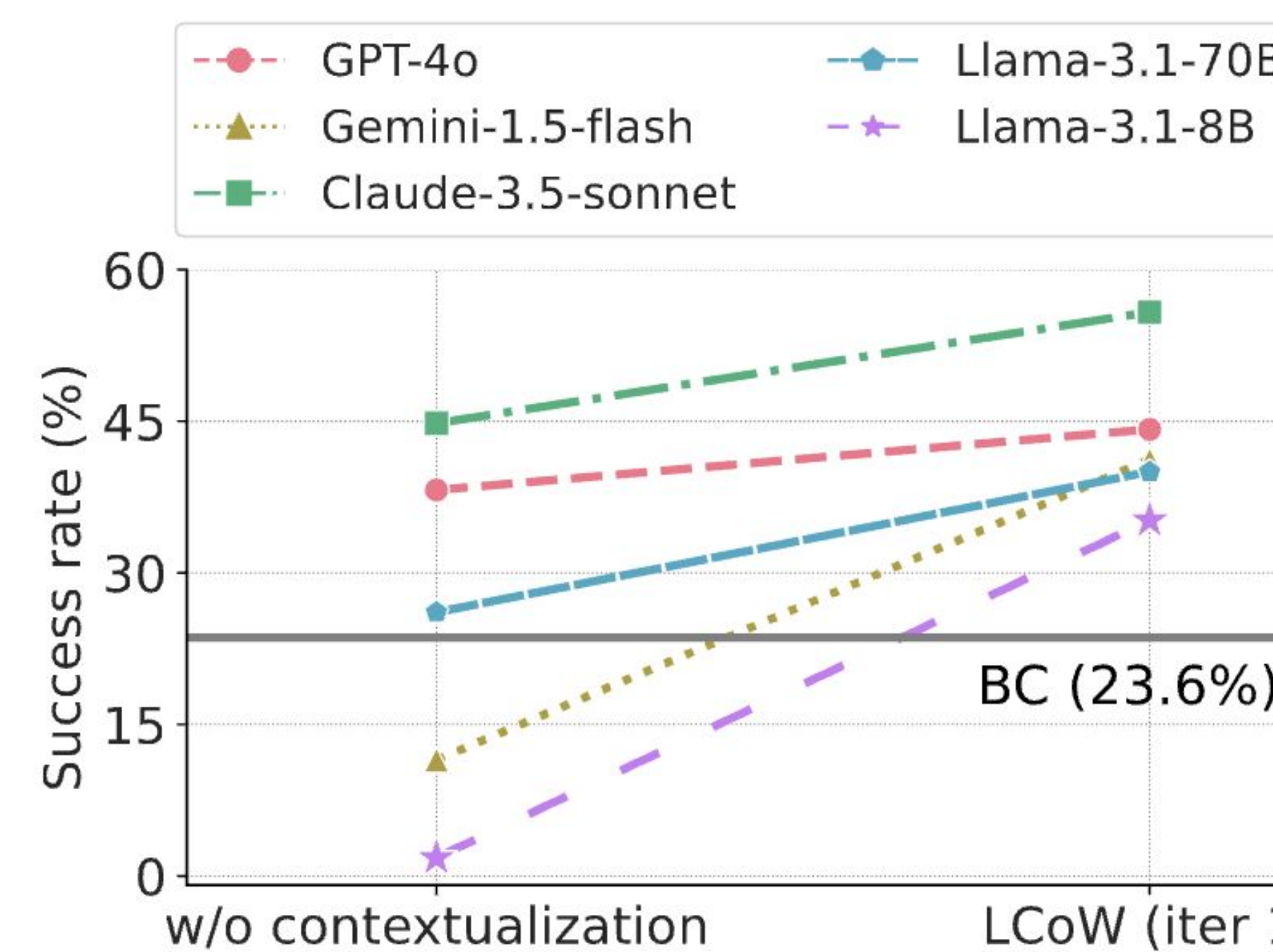


Figure 3. Comparison to Llama-3.1-8B agent trained via Behavior cloning (BC)

## Analysis

### Generalization capability

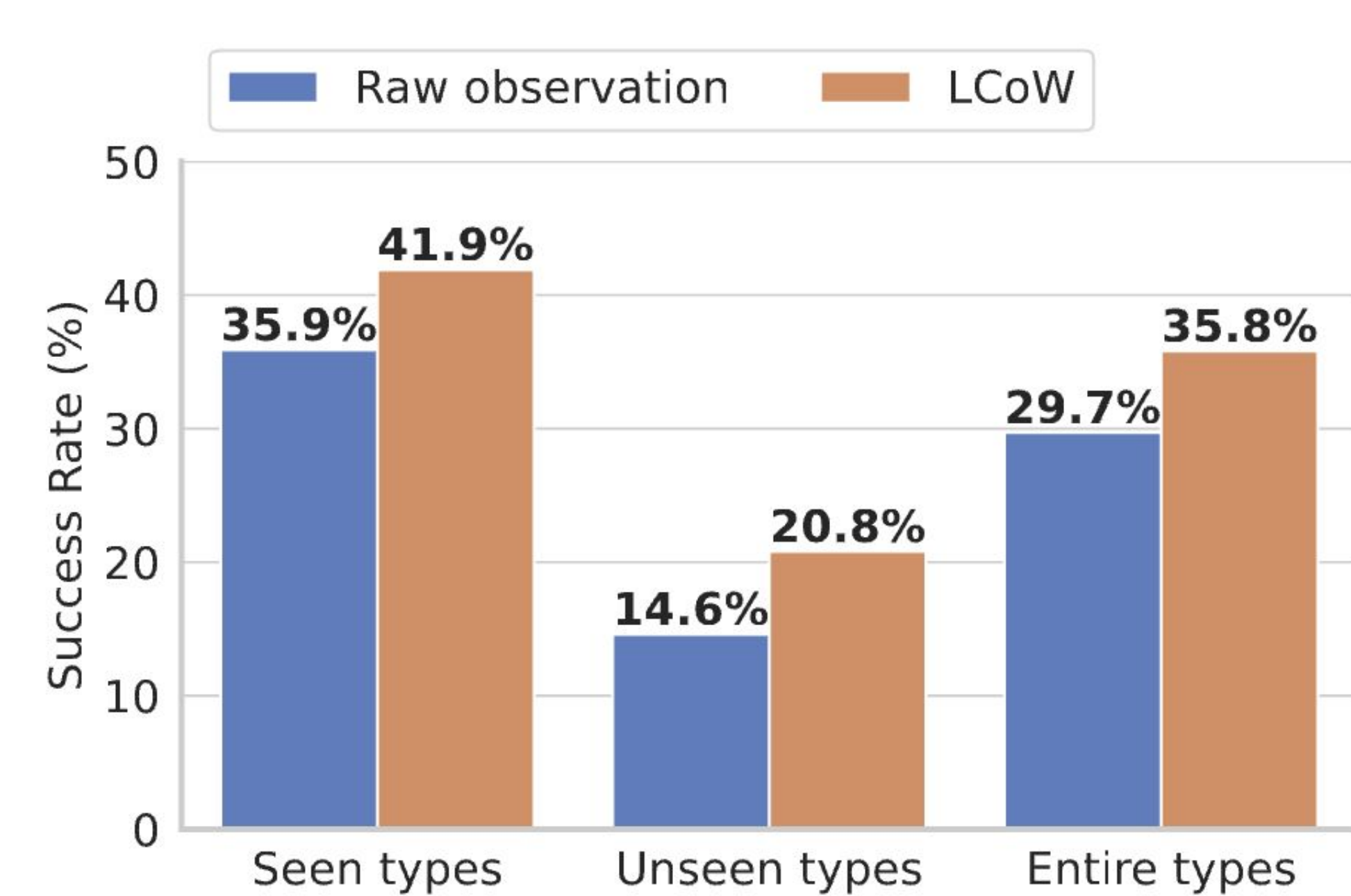


Figure 4. Effectiveness of LCoW in WebArena-Lite, and generalization to unseen task types.

- LCoW demonstrates 6% success rate improvement in both seen-type and unseen-type tasks\*, **indicating generalization capability**.

\*Given a task “What is the top-3 best-selling product in 2023” used in training, we test with tasks:

- seen-type: sharing similar task templates (e.g., “What is the top-1 best-selling product in 2022”)
- unseen-type: not sharing task templates (e.g., “Tell me the email address, name, phone number of the customer who has the most cancellations in the history”)

### Qualitative analysis

Example 2 (WebArena)	Example 3 (WebArena)
<p><b>Instruction:</b> Tell me the status of my latest order and when will it arrive.</p> <p><b>Contextualized web page observation:</b></p> <pre>[1415] strong '' [1416] link 'View All' [1420] table 'Recent Orders' [1421] caption '' [1422] rowgroup '' [1423] row '' [1424] columnheader 'Order #' [1425] columnheader 'Date' [1426] columnheader 'Ship To' [1427] columnheader 'Order Total' [1428] columnheader 'Status' [1429] columnheader 'Action' [1430] rowgroup '' [1431] row '' [1432] gridcell '000000170' [1433] gridcell '5/17/23' [1434] gridcell 'Emma Lopez' [1435] gridcell '9365.42' [1436] gridcell 'Canceled' [1437] gridcell 'View Order' [1438] gridcell 'Reorder' [1439] link 'View Order' [1441] link 'Reorder'</pre> <p>This extraction shows the "Recent Orders" section, which contains a table with information about recent orders. The table includes columns for Order #, Date, Ship To, Order Total, Status, and Action.</p> <p>The "View All" link [1416] likely leads to a page with more detailed information about all orders.</p> <p>The first row in the table [1431] contains information about the latest order:</p> <pre>=Order number: 000000170 =Date: 5/17/23 =Ship To: Emma Lopez =Order Total: \$9365.42 =Status: Canceled =Action: View Order [1439] or Reorder [1441]</pre>	<p><b>Instruction:</b> Edit my post on Star Trek Starfleet Academy series by adding a line to the body that says "Every watch makes me feel like a kid again."</p> <p><b>Contextualized web page observation:</b></p> <pre>[68] button 'MarvelsGrantMan136', focused,       hasPopup='menu', expanded=True       This is the currently focused and expanded user account menu button.       It contains the user's username and is likely to lead to profile settings.</pre> <pre>[74] list ''       This list contains the submenu items under the user account menu.</pre> <pre>[80] listitem '' [81] link 'Profile'</pre> <p>This is the "Profile" link we need to click to access the user's profile settings. It's nested under the user account menu.</p> <p>These elements are crucial for navigating to the user's profile settings, where we can then look for options to edit posts or submissions. The "Profile" link [81] is particularly important as it's the next element we need to interact with to progress towards our goal of editing the post.</p>

- (Left) Contextualization module **extracts information of UI element**, providing better context to the LLM agent (the latest order from lengthy table).
- (Right) Contextualization module **explains the effect of manipulating UI element** (explanation on the `Profile` element).

## Conclusion

- We propose a novel framework for enhancing LLM agents performances, by decoupling perception from decisions.
- With contextualization, LCoW demonstrates significant improvement on the web agents of varying scales.

Check out for more details in this QR code →

