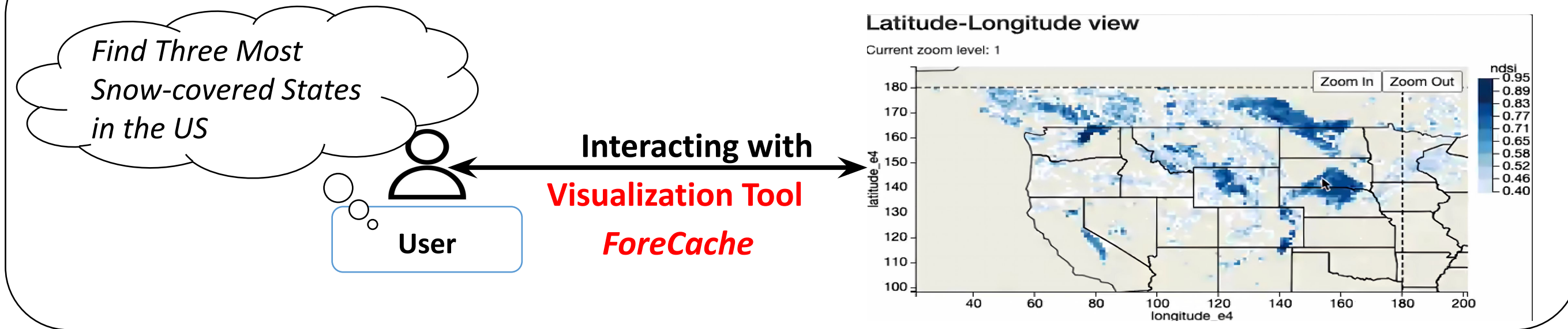


## 1. Exploratory Visual Analysis

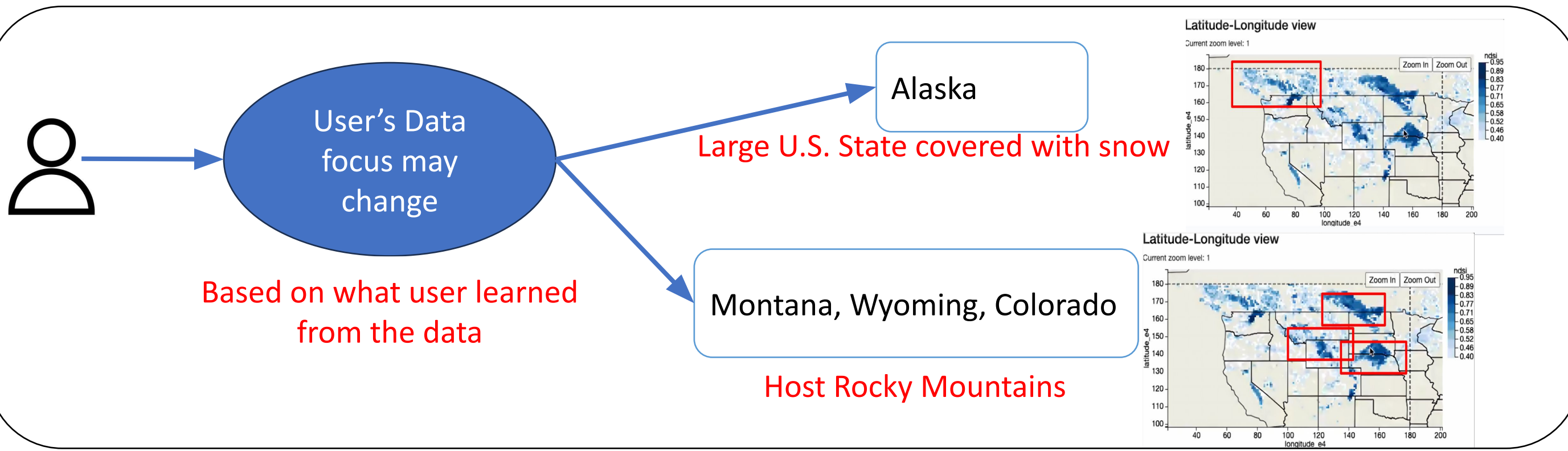
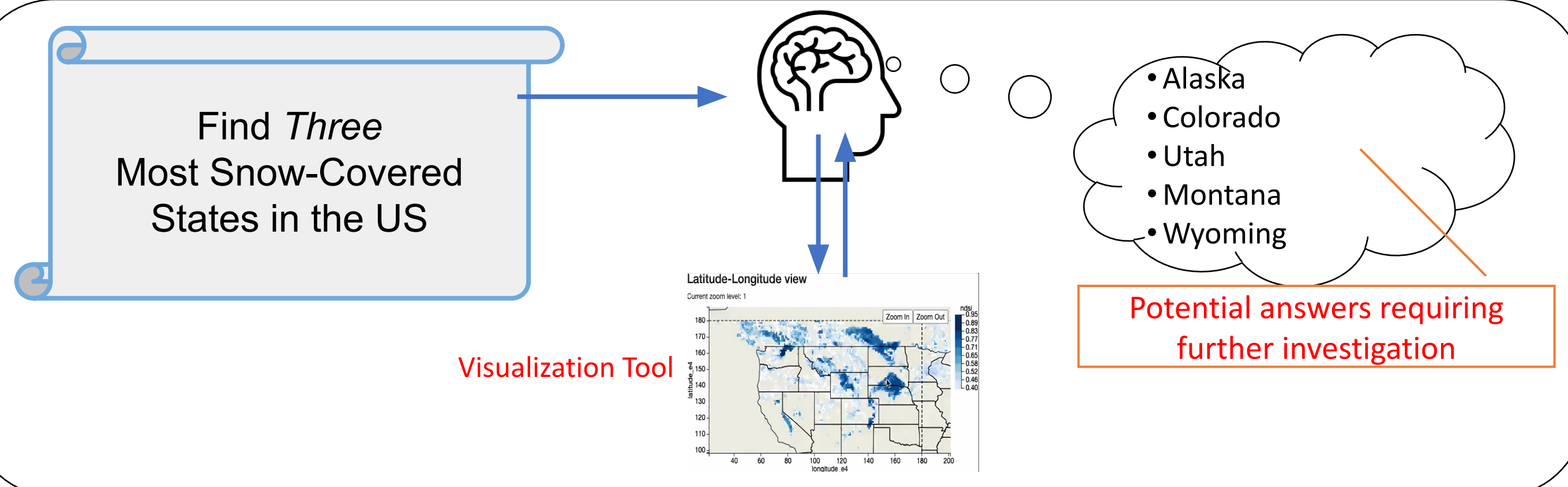
Finding **interesting hypotheses** and previously unseen **insights**

### Example



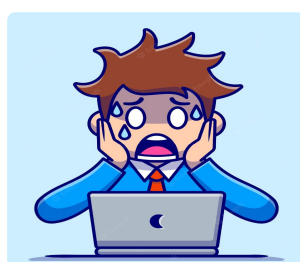
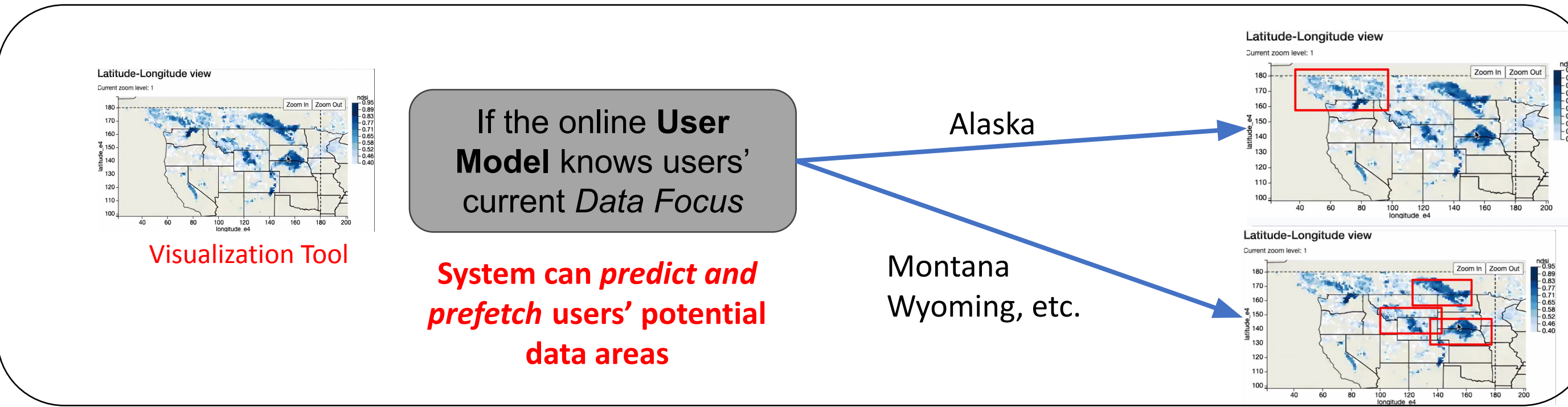
## 2. Users' Exploration Behavior Evolve as They Learn About Data

Potentially influencing: User's Data focus, which data area user wants to explore



User Learning: Learn, Improve, Overcome

## 3. Modeling User Learning Online During Exploration Benefits Systems



Current systems assume users do not learn or change their exploration strategies.

## 4. Research Questions

How does users' exploration behavior evolve?

Can we model user learning using existing human learning algorithms?



## 5. Analyzing User Behavior on Diverse Exploration Tasks

Exploration task characteristics that may influence user behavior

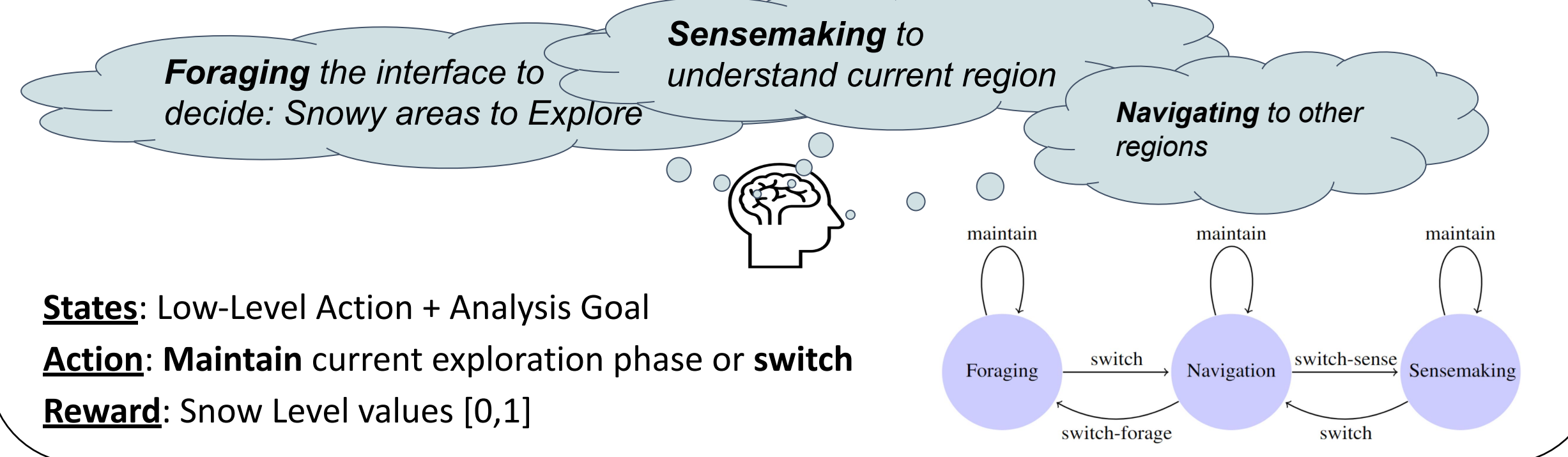
- **Open-endedness:** Clarity of task objectives
- **Prior Experience:** Familiarity with the dataset, task, and interface.
- **Time-Restriction:** Time limit for task completion
- **Tool Complexity:** Action space, amount of information in the visualization tool

We use widely studied studies from the visualization community encapsulating diverse task characteristics

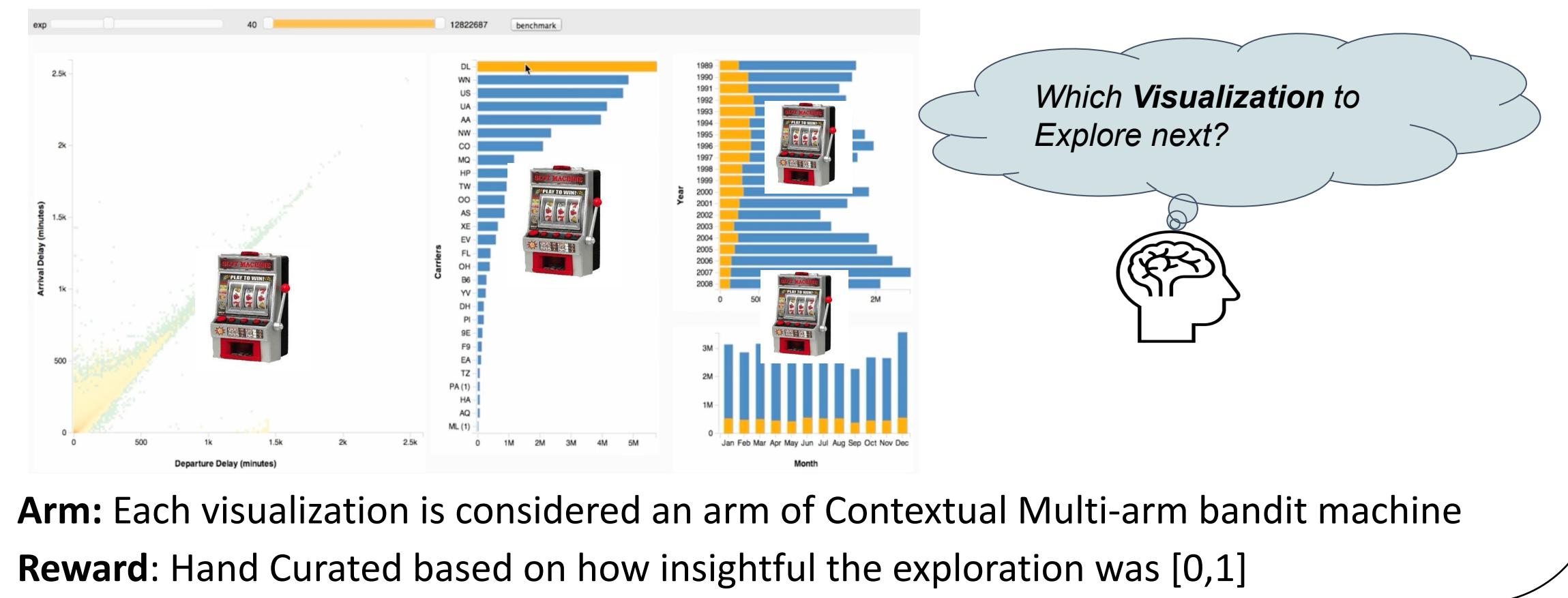
Tool	imMens	ForeCache
Data	1. Airplane on-time performance 2. BrightKite travel history data	NASA Snow cover satellite data
Exploration interface	E.g. For Brightkite, imMens shows 4 visualizations on travelers activities on a geographical map over years, months and hours.	Deep blue areas has higher snow cover.
Task	Report any interesting pattern from data	Find top 3 snow areas in zoom level 4

## 7. Formalizing Learning Problems with Online Learning Frameworks

Formalizing user learning in ForeCache using **Markov Decision Process**



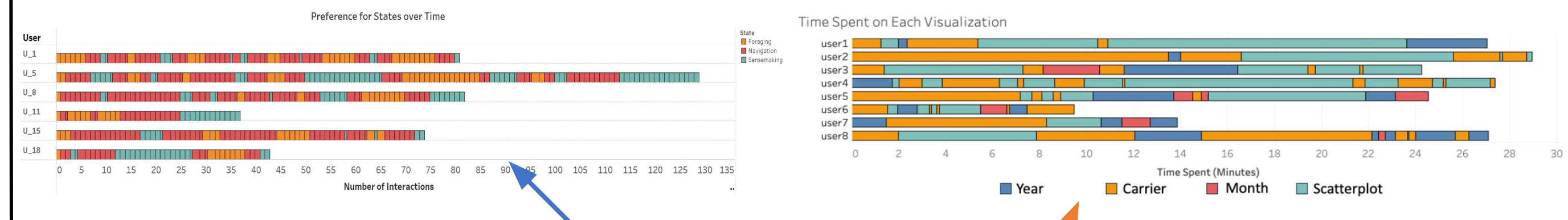
Formalizing user learning in imMens using **Contextual Multi-armed Bandit**



## 8. Statistical Analysis of Changes in Users' Behavior

Consider, each exploration session is divided into two halves.

Question: Does users' behavior significantly change in the final half?

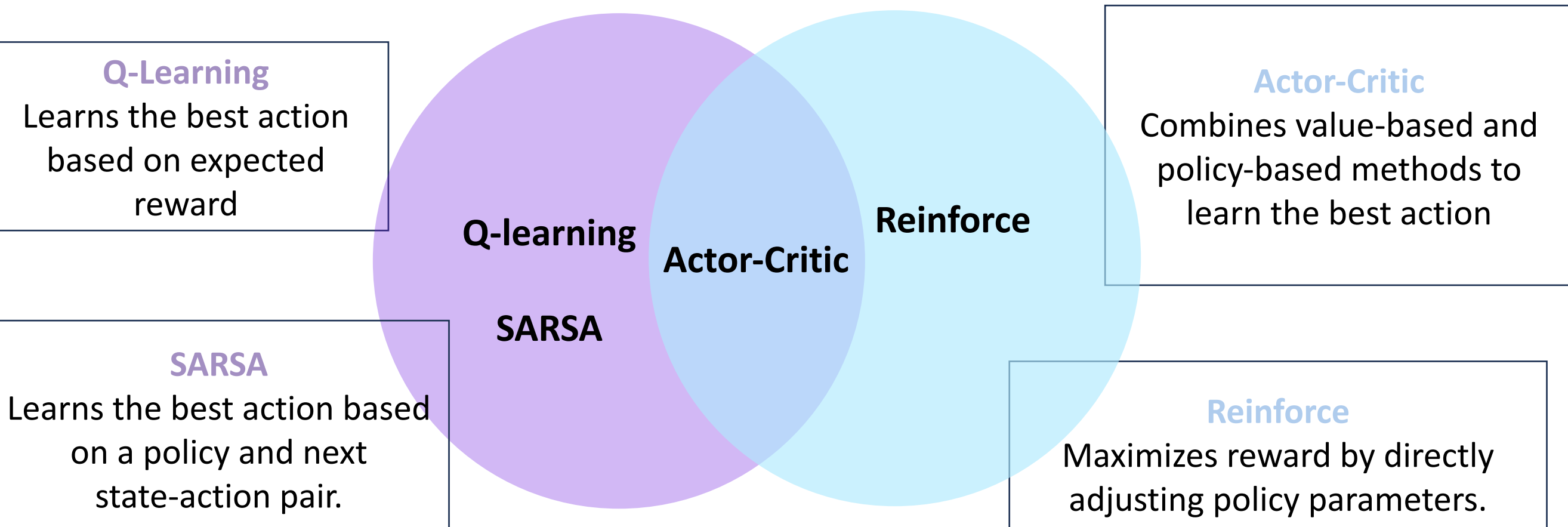


Users' different exploration phases and preferred data areas over time

Statistical analysis using **Wilcoxon Signed Rank test** on users' exploration behavior

## 9. Learning Algorithms Used for Modeling

Human Learning algorithms in Cognitive Psychology, Neuroscience, Economics, Game Theory

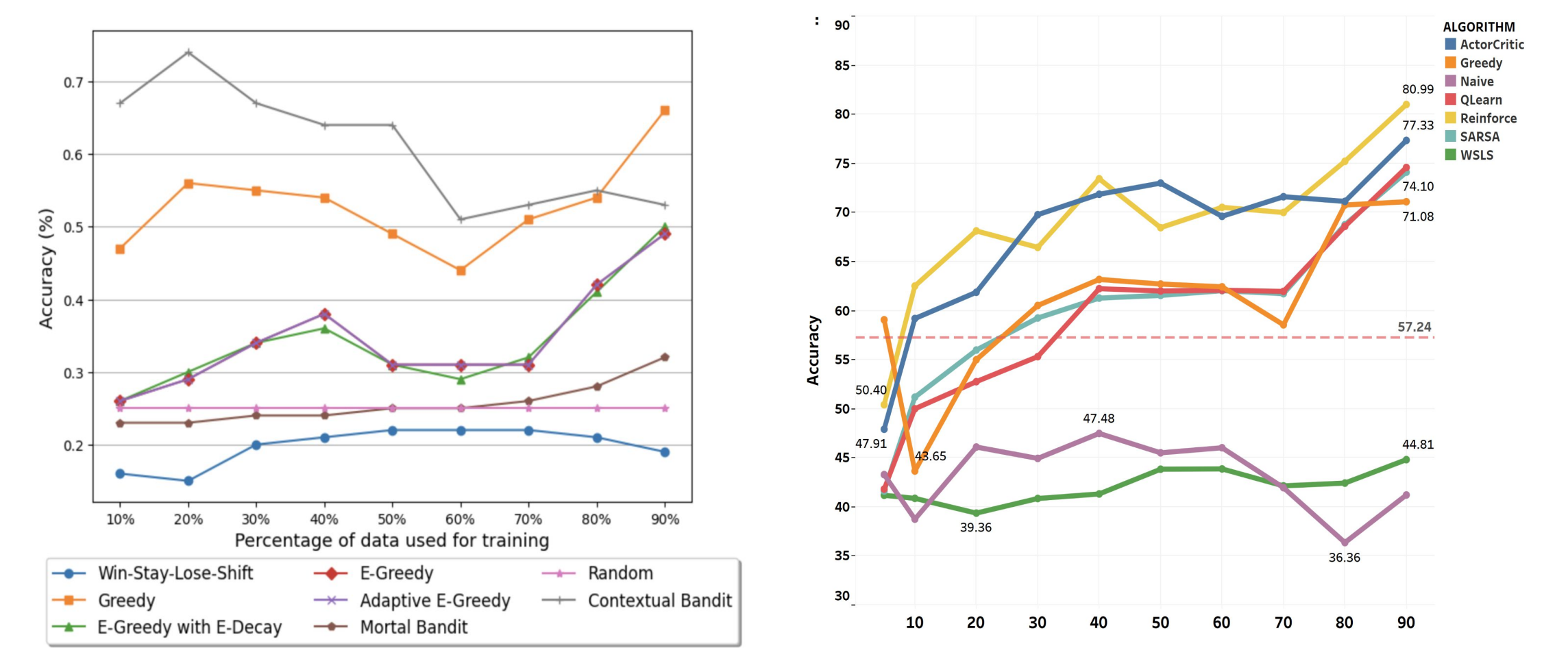


Also, Different Multi-Arm Bandit Approaches

## 10. Evaluation of Modeling Algorithms

Question: How do we check if the algorithms are capturing user learning?

Answer: Prediction of next action as a Proxy



- Simple algorithms such as Greedy are competitive enough
- Like Humans more experience is better for the learning models
- Having more features is also beneficial (e.g., Contextual Bandit)

For a more comprehensive detail on all exploration tasks, learning problem formalization, algorithms and discussions scan this QR code

